Feasibility of Targeted Invasive Plant Grazing in Metro Vancouver

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Executive Summary

This report assesses the feasibility of targeted invasive plant grazing in Metro Vancouver, reviewing the efficacy, challenges, and considerations of targeted grazing treatments for control of invasive plants. Fourteen targeted grazing practitioners were interviewed to assess the operational feasibility of targeted grazing treatments. Seven target species were selected, and review of available literature and data enabled detailed assessments of targeted grazing versus other control treatments, comparing efficacy and costs. Recommended approaches for effective control of each species were provided. Generally, control treatments must be repeated and used in combination with other complimentary methods, include monitoring plans and follow-up action as needed to prevent recolonization, in conjunction with effective restoration/revegetation plans to re-establish competitive native communities.

The efficacy of targeted grazing was determined for seven target species:

Invasive Species	Control Efficacy
Giant Hogweed	High
English and Irish Ivies	High
Himalayan Balsam	High
Wild Chervil	Moderate-High
Himalayan Blackberry	Moderate
Scotch Broom	Moderate
Purple Loosestrife	Low-Moderate

Targeted grazing treatment application costs were found to be comparable to mowing and manual control efforts; however additional costs may be associated with the logistical requirements necessary to enable targeted grazing. These costs are difficult to quantify, highly variable, and site specific.

Significant logistical considerations must be addressed prior to implementing targeted grazing treatments, ranging from addressing legal requirements, public communication, partnerships with bylaw enforcement agencies and police, animal husbandry requirements, biosecurity considerations, provision of pre-grazing data, post-grazing monitoring, and effective restoration. Adequate funding and staff resources must be in place to support all the logistical considerations. If treatments are applied ad-hoc and do not meet the recommended timing, frequency, and duration, control will be ineffective.

Goats are suggested as the most suitable livestock (versus sheep, pigs, or cattle) to perform targeted grazing based on efficacy, ease of handling, public perception, and availability of herds. There is a shortage of targeted grazing practitioners in Western Canada and none in the Lower Mainland, but five practitioners expressed interest and willingness to work in the Metro Vancouver Region.

Potential carbon implications were reviewed as part of a case study for targeted grazing of Himalayan blackberry at Metro Vancouver's Aldergrove Regional Park. Carbon dioxide emissions associated with targeted grazing may be higher than other control methods due to the need for transportation of herds from outside the region.

A 3-5 year operational grazing plan, field testing recommendations, and monitoring protocols were provided. Specific cost estimates for targeted grazing at Aldergrove Regional Park range from $12,000-$56,000 per year based on practitioner review by Tammy Salmon, practitioner quotes from interviews, and frequency and duration requirements from literature review. While the cost estimates from literature note that maximum costs for grazing treatment of the target area could range up to $186,600 annually – a realistic annual budget should be $40,000 for a grazing practitioner and $30,000/year for a part-time coordinator.

Targeted grazing treatments in Metro Vancouver are only feasible if logistical considerations can be met, and funding and staff resources have been allocated to support the long-term partnerships necessary for effective control. If treatments are applied ad-hoc and do not meet the recommended timing, frequency, and duration, control will be ineffective.

If Metro Vancouver decides to proceed with field-testing, Aldergrove Regional Park could be a suitable location, with the caveat that logistical considerations must be adequately addressed, and long-term funding must be secured prior to initiating targeted grazing treatments. Success requires implementing long-term treatments focused on consistency in application, monitoring, regrowth management, and restoration.

Table of Contents

List of Tables

List of Figures

Introduction

Invasive plants represent a suite of threats to biodiversity, agricultural systems, infrastructure, human health and safety, and recreational values. Although herbicides can be an effective solution to addressing the spread and abundance of invasive plants, they may have undesirable impacts in sensitive ecosystems, their use may be restricted in some areas (eg. riparian areas, or areas with bylaws preventing their use), or there may be a desire to explore and utilize herbicide-free control options. Targeted grazing of invasive plants by livestock is being explored as an herbicide-free approach, but does include challenges in application and management, and may result in negative unintended consequences if not properly scoped and applied. This feasibility assessment will review the challenges, cost effectiveness, and efficacy of targeted grazing for control of invasive plants, with an ultimate outcome of developing a set of recommendations and field-testing protocols for targeted grazing in Metro Vancouver, and further explore the control of Himalayan blackberry in Aldergrove Regional Park as a case study.

> Targeted grazing is defined as: '…the application of a specific kind of livestock at a determined season, duration, and intensity to accomplish defined vegetation or landscape goals.' (Launchbaugh & Walker, 2006)

As a practice, targeted grazing uses the timing, frequency, intensity, and selectivity of grazing/browsing to apply herbivory pressure on specified plant species or sections of the landscape (Bailey et al., 2019; Rinella & Bellows, 2016). This concept is also known as prescribed grazing or managed herbivory, and provides managers with an alternative to mechanical, chemical, or prescribed fire treatments to manipulate vegetation (Bailey et al., 2019; R. Frost et al., 2012; Launchbaugh & Walker, 2006). Livestock is focused on the area of interest through fencing, herding, or the placement of supplements to defoliate and/or trample the species or area of interest to achieve vegetation management objectives (Bailey et al., 2019; Rinella & Bellows, 2016). Targeted grazing can be highly effective as an invasive weed management tool if the application is precise (Launchbaugh & Walker, 2006; Popay & Field, 1996). For the best success it should be used in combination with other weed management techniques as part of an ongoing integrated weed management system (Bailey et al., 2019; Popay & Field, 1996). Effective targeted grazing treatments require a knowledge of plant ecology, livestock nutrition, livestock foraging behaviour, livestock handling/management, and site specific ecological attributes (Bailey et al., 2019; Launchbaugh & Walker, 2006; Rinella & Bellows, 2016).

Methodology and Suitable Target Plant Species

A preliminary assessment was undertaken of Metro Vancouver's 13 priority invasive plant species to determine suitability of each species for control by targeted grazing. This preliminary assessment resulted in the removal of six invasive plant species from further consideration for the project (See Appendix 1 for further discussion) (Table 1). Seven invasive plant species were determined as suitable for control by targeted grazing. Each plant species was assessed for efficacy, palatability, toxicity, digestive efficiency, and grazing timing and frequency, as summarized in Table 2, discussed in the following section, with additional details found in Appendix 2.

Table 1. Preliminary assessment of priority invasive plant species.

Selected for Project?[a]	Species	Toxicity	Palatability	Site Considerations	Targeted Grazing Effective?[b]
YES	**Giant Hogweed**	Mild toxicity	Palatable	Found in moist areas, potential issues with erosion/compaction/riparian use	**YES** Herd selection important
YES	**English and Irish Ivies**	Mild toxicity	Palatable		**YES** Herd selection important
YES	**Himalayan Balsam**	Non-toxic	Palatable	Found in moist areas along waterways, potential issues with erosion/compaction/riparian use	**YES**
YES	**Himalayan Blackberry**	Non-toxic	Palatable		**YES** As a complementary treatment
YES	**Wild Chervil**	Non-toxic	Young plants palatable, unpalatable near maturity Low nutritional value	Found in moist areas, potential issues with erosion/compaction/riparian use	**YES** As a complementary treatment
YES	**Purple Loosestrife**	Non-toxic	Unpalatable generally Palatable to goats	Found along waterways, potential issues with erosion/compaction/riparian	**YES** As a complementary treatment
YES	**Scotch Broom**	Mild toxicity	Unpalatable generally Palatable to goats		**YES** As a complementary treatment
NO	**Knotweed**	Non-toxic	Palatable	Found along waterways, potential issues with erosion/compaction/riparian	**NO** Short-term reduction of above ground plant matter, doesn't address rhizome system
NO	**Reed Canarygrass**	Toxicity depends on species variety and associated alkaloids	Palatable	Found in moist areas, potential issues with erosion/compaction/riparian use	**NO** Short-term reduction of above ground biomass
NO	**English Holly**	Foliage mildly toxic, berries very toxic	Unpalatable		**NO** Less than 50% effective
NO	**Yellow Archangel**	Non-toxic	N/A		**N/A** No information on grazing, but cutting/mowing is not effective due to rapid regrowth from roots
NO	**Parrot's Feather**	Non-toxic	N/A	Found only in waterbodies - not compatible with grazing	**N/A** No information on grazing available
NO	**Yellow Flag Iris**	Very toxic	Unpalatable		**NO**

a Green indicates that plant species was selected for assessment as part of feasibility study, red indicates that it was not selected.
b Green indicates that targeted grazing is an effective control treatment, yellow indicates that targeted grazing is effective as a complimentary treatment, and red indicates that targeted grazing is either not effective (less than 50% efficacy), no information was available, or that the plant is too toxic for livestock consumption.

Target Plant Comparisons

Estimated treatment cost and efficacy comparisons for target plant species were compiled through a thorough literature review and cost data provided by Metro Vancouver. These values are presented in Tables 2 & 3. Recommendations are based on review of target species characteristics, control method efficacy, and estimated costs.

Table 2. Summary of suitable target plant species assessment.

Target Invasive Plant Species	Efficacy[a]	Palatability	Toxicity	Digestive Efficiency	Grazing Timing and Frequency	Duration (Years)[c]	Livestock Recommendation
Giant Hogweed	**High**	**High**	Mild Toxic sap causes photosensitive dermatitis, mild glycosides and flavinoids = mild toxicity	Assumed **high** due to delicate seeds NSSA[b]	2 treatments per growing season: Spring and late summer	7	Sheep and goats
English and Irish Ivies	**High**	**High**	Mild Contains hederin	Assumed **moderate** due to hard-coated seeds NSSA[b]	1 treatment per growing season: applied during active growth under dry soil conditions	2	Goats
Himalayan Balsam	**High**	**High**	Non-toxic	Assumed **high** due to delicate seeds NSSA[b]	2 treatments per growing season: Spring and late summer	2	Sheep and goats
Himalayan Blackberry	**Moderate**	**High**	Non-toxic	Assumed **moderate** due to hard-coated seeds NSSA[b]	2 treatments per growing season: Spring and summer	3-5	Goats
Purple Loosestrife	**Low-Moderate**	**Low** **Moderately** palatable to goats	Non-toxic	Assumed **high** due to delicate seeds NSSA[b]	1 or more treatments per growing season: applied during active growth	3+	Goats
Scotch Broom	**Moderate**	**Low** Palatable to goats	Mild Contains quinolizidine alkaloids, toxicity not been reported in goats	**Moderate** 8% of seeds viable following digestion by goats	1 continuous treatment applied season long during active growth	4-30	Goats
Wild Chervil	**Moderate-High**	Palatability declines with age	Non-toxic	Assumed **high** due to delicate seeds NSSA[b]	1 or more treatments per growing season: applied starting in early spring	2	Goats

a Efficacy estimates are based on application of recommended grazing timing, frequency, and duration, in combination with ongoing monitoring.
b NSSA – No Specific Studies Available
c Duration of active eradication treatments. All treatments require ongoing monitoring past this window and follow-up control efforts when necessary to address any regrowth.

Table 3. Cost[a] per m^2 and efficacy[b] comparisons of treatments on target species. Costs represent a single application and are estimated using best available data from literature, practitioner interviews, and Metro Vancouver

Target Species	Targeted Grazing[c]	Chemical[d]	Mechanical[e]/Manual[f]	Biological Control	Cultural Control	Treatment Recommendations
Giant Hogweed	$0.15-$8.20	$0.30-$2	Taproot Cutting $0.36-$50 Hand Pulling $0.90-$50 Mowing $0.90-$13	$N/A	Fire $ N/A	Grazing, Chemical, Taproot Cutting, or Hand Pulling
English and Irish Ivies	$0.15-$2	$0.30-$2	Hand Pulling/Cutting $0.35-$16	$N/A	Fire $ N/A Heat Treatment $ N/A Mulch Application $ N/A	Grazing, Hand Pulling/Cutting, or Mulch Application
Himalayan Balsam	$0.15-$2	$0.30-$18	Mowing $0.90-$18 Hand Pulling $0.90-$18	$N/A	Fire $ N/A	Grazing, Chemical, Mowing, or Hand Pulling
Himalayan Blackberry	$0.15-$2	$0.30-$2	Hand Pulling $0.30-$12 Mowing $0.13-$0.50 Bulldozing $0.30-$1.22	$N/A $N/A	Fire $ N/A	Hand Pulling, Grazing, Chemical, Mowing, or Bulldozing
Purple Loosestrife	$0.15-$2	$0.30-$2	Hand Pulling $0.30-$12 Mowing $0.13-$0.50 Hand Cutting $0.30-$12	*Neogalerucella* beetles $N/A	Fire $ N/A Flooding $ N/A	Biocontrol, Hand Pulling, or Chemical
Scotch Broom	$0.15-$2	$0.03-$2	Hand Pulling/Cutting $0.65 Mowing $0.50-$2 Mulching $0.07 Tilling $0.10-$2	$N/A	Fire $ N/A Shading $ N/A	Hand Pulling/Cutting, Chemical, or Grazing
Wild Chervil	$0.15-$2	$4.62	Hand Pulling $0.30-$12 Tilling $0.30-$12 Mowing $0.25-$1 Seed Head Clipping $0.30-$12	$N/A	Fire $ N/A Smothering $ N/A	Grazing, Hand Pulling, Tilling, Mowing, and Smothering

a Estimated costs solely reflect treatment costs and do not include other costs that may be necessary to enable treatment application (e.g. logistical and legal considerations).
b Efficacy estimates based on treatment applied as recommended, in combination with ongoing monitoring and follow up treatments.
c Grazing treatments may be limited by significant logistical considerations and are not suitable for riparian or wetland ecosystems
d Chemical treatment is not permitted in riparian and wetland ecosystems
e Mowing treatment options may not be possible in remote areas and steep slopes
f Manual removal would be labour intensive for large infestations, but costs would may be considerably less if using volunteers

Efficacy:
High
Moderate-High
Moderate
Low-Moderate
Low

Giant Hogweed

Giant hogweed (*Heracleum mantegazzianum*) is a highly fecund, broadleaf, herbaceous perennial that can reach up to 5m in height (CABI, 2020c; Gucker, 2009; Page et al., 2006). Native to Russia, its vigorous growth and large size result in changes in vegetation, forming a monoculture and rapidly replacing all other plants save trees, resulting in reductions in biodiversity, and soil erosion issues when herbaceous matter dies off during the winter (CABI, 2020c; Pyšek et al., 2007; Williamson & Forbes, 1982). Propagated entirely by seed, which is produced at very high rates (between 5,000 to 100,000 seeds per plant) early germination provides a competitive advantage, allowing giant hogweed to outcompete native plants, enabling rapid spread (CABI, 2020b; Pysek et al., 2007). Additionally, giant hogweed sap contains compounds called furanocoumarins, which when in contact with skin, react with sunlight, resulting in painful blisters, recurrent dermatitis, and light sensitivity (Drever & Hunter, 1970; Gucker, 2009; Morton, 1975; Tiley et al., 1996). This represents a significant human health concern in addition to the negative environmental impacts of giant hogweed.

Giant hogweed can tolerate a wide range of climatic and soil conditions, but in the Metro Vancouver region it tends to be found in areas with moist soils, including riparian areas along streams and rivers, forest edges, gardens, transportation corridors and vacant lots (CABI, 2020c; Metro Vancouver, 2019b; Page et al., 2006; Pyšek et al., 2007).

Efficacy of Targeted Grazing

Targeted grazing is considered an effective control method for giant hogweed, and is associated with both the suppression and eradication of hogweed infestations (Andersen & Calov, 1996; Andersen, 1994; Nielsen et al., 2005; Tiley et al., 1996). Although light grazing does not provide effective control, higher intensity grazing treatments reduce density and distribution of giant hogweed, and in longer-term applications (7 years) giant hogweed has been eradicated by grazing, including any new germinants or viable seeds in the seed bank (Andersen & Calov, 1996; Nielsen et al., 2005b). Part of the efficacy is associated with trampling in addition to grazing; higher densities of animals will encourage trampling impacts and help ensure that a high proportion of plants are grazed and subsequently unable to flower and produce seed (Morton, 1975; Tiley et al., 1996; Wright, 1984).

Grazing treatments are most effective when plants are small, as livestock will select for them. Grazing animals are able to remove most of the plant, preventing photosynthesis, and depleting regrowth potential (Andersen, 1994; Buttenschon & Nielsen, 2007; Nielsen et al., 2005; Page et al., 2006). To reduce negative impacts to grazing animals and increase efficacy of grazing, a mechanical cut of hogweed plants is suggested. A mechanical cut will allow other plants to establish and grow; this provides grazers a mixed diet, reduces vigour of hogweed plants and provides tender regrowth for grazers to select for (Nielsen et al., 2005). Target areas fenced should include any areas where seed dispersal may have occurred, to ensure that the grazing treatment captures new germinants (Nielsen et al., 2005).

Comparison to Other Control Methods

The efficacy of control methods for giant hogweed is affected by high levels of seed production, a viable long-lived seed bank, and a protected root crown that enables aggressive re-sprouting (CABI, 2020b; Pysek et al., 2007). All treatments require monitoring plans along with follow-up treatments prevent recolonization in conjunction with restoration/revegetation plans (King County Noxious Weed Control Program, 2010; Nielsen et al., 2007; Nielsen et al., 2005).

Biocontrol

No current biocontrol agents have been developed, although they are currently under investigation (CABI, 2020c; Page et al., 2006; Wittenberg et al., 2003).

Chemical Control

Giant hogweed is sensitive to many herbicides, and they are a highly effective control option (CABI, 2020c; Page et al., 2006). Glyphosate, imazapic, imazapyr, trichlopyr, dicamba, 2,4-D, clopyralid, metsulfuron, chlorsulfuron, and Aminopyralid all provide good control of hogweed (DiTomaso & Kyser, 2013; Nielsen et al., 2007; Page et al., 2006; Tiley et al., 1996). Imazapyr is a residual herbicide that will also prevent germination, providing another level of control efficacy (CABI, 2020c). Glyphosate has shown the highest level of efficacy overall (Nielsen et al., 2007). For the best effect, herbicides should be applied through foliar application or stem injection early in the growing season, when plants are 20-50 cm high, with treatments repeated annually until hogweed no longer recurs in the area (Nielsen et al., 2007; Page et al., 2006; Tiley et al., 1996).

Chemical control is complicated by restrictions around chemical use in riparian areas, one of the preferred habitats of giant hogweed (CABI, 2020c; Metro Vancouver, 2019b; Page et al., 2006; Pyšek et al., 2007).

Mechanical Control

Mechanical control is complicated by the phototoxic compounds found in hogweed sap, which represents a significant health hazard to workers (Drever & Hunter, 1970; Gucker, 2009; Morton, 1975; Tiley et al., 1996). Health and safety protocols should be strictly adhered to during any mechanical control efforts. Taproot cutting is the most effective mechanical control method, where severing the roots below the soil (8-10 cm deep) will kill the plant, with the highest efficacy found when implemented in the spring (Buttenschon & Nielsen, 2007; Nielsen et al., 2007; Tiley et al., 1996). Taproot cutting should be repeated again in the summer to ensure all plants have been treated, combined with ongoing monitoring to address new plants germinating from the seed bank (Pyšek et al., 2007). Tilling can be effective in agricultural areas (Tiley et al., 1996). Hand pulling is effective on young plants and for small infestations, large plants increase safety risk, and pulling is impractical for large infestations (Metro Vancouver, 2019b; Page et al., 2006). Mowing/scything does not provide long-term control as it doesn't address roots, and rapid regrowth from roots will occur (CABI, 2020c). Spring cutting can reduce seed production (Tiley et al., 1996), but cutting must be repeated consistently during the growing season and over many years to have an effect on plants, even four cuttings a year for two consecutive years has not resulted in the death of hogweed plants (Nielsen et al., 2007). Additionally, seed can be spread during mowing/cutting treatments. Appropriate timing of treatment is necessary to ensure that treatments do not occur during seed set (Page et al., 2006). Removing flower heads is effective in reducing seed production and hogweed spread, but must be well-timed to ensure that plants do not regenerate new flowers and viable seeds (CABI, 2020b; Metro Vancouver, 2019b; Nielsen et al., 2007; Page et al., 2006).

Cultural Control

There is no information available on the efficacy of fire on giant hogweed, although heat treatment has been considered a potential effective control method (Page et al., 2006). Fire is considered neither practical nor effective on giant hogweed as its protected root crown will enable post-fire sprouting, and burnt areas will encourage seedling germination and growth (DiTomaso & Kyser, 2013; Gucker, 2009).

Control Comparisons

All giant hogweed control options must take into consideration the seed bank and potential for reestablishment from dormant seed (Page et al., 2006). Ongoing monitoring for 10 years is suggested, with additional control treatments as necessary (Andersen & Calov, 1996; Nielsen et al., 2005; Rajmis et al., 2016; Williamson & Forbes, 1982). While very little cost-benefit research has been conducted on giant hogweed, an analysis of control over 10 years in Germany found that herbicide spot-spraying was the lowest cost and highest efficacy option (Rajmis et al., 2016), but chemical control is not suitable for many of the habitats giant hogweed occupies in the Metro Vancouver region. Estimated costs presented in Table 4 for targeted grazing control include fencing, shelter, maintenance of infrastructure, and administrative/logistics considerations (Rajmis et al., 2016).

Metro Vancouver's Best Management Practices for Giant Hogweed (Metro Vancouver, 2019b), current (as of 2019) recommends chemical control, and taproot cutting and flower removal as mechanical control options. They do not recommend grazing. However, that guidance was compiled without an extensive review of targeted grazing literature, and it updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Giant Hogweed Summary

Based on costs and efficacy of treatment (Table 4), it appears that targeted grazing would be more cost effective than hand pulling or taproot cutting, but less cost effective than mowing or chemical treatment. Chemical treatment has the lowest cost and highest levels of efficacy but is not suitable for many giant hogweed habitats in Metro Vancouver. An integrated weed management approach is recommended, comprised of mechanical control efforts followed by high intensity grazing repeated twice within the growing season (spring and summer), over a 7-year period to exhaust the seed bank (reduced time and effort levels will occur as infestation and seed bank is reduced), with ongoing monitoring and treatments as required. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 4. Summary of control methods for giant hogweed, template adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m² per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m²	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • sheep and goat grazing • treatment repeated within seasons and over years • treatment applied when plants are small • high animal densities • a mechanical cut prior to grazing	\$0.15-\$8.20	2	7	\$2.10-\$114.80	• Good for sites with difficult terrain or environmental sensitivities • May result in additional bare soil or erosion • Ensuring other plants are available for grazing will reduce potential health impacts on animals • Fenced area should include any areas where seed dispersal may have occurred
Chemical	Many options- for broadcast, spot spraying, or stem injection	Highly effective if sprayed/injected early in the growing season	\$0.30-\$2	1	1-7	\$0.30-\$14	• Requires multiple applications • High potential for non-target plant impacts • Not acceptable near water or riparian areas
Mechanical Mowing	Area is mowed or cut multiple times per year for several years	Effective when frequency and duration are sufficient to exhaust seed bank (7+ years)	\$0.90-\$13	2-4	7	\$12.60-\$364	• Health and safety risk with hogweed sap • Requires flat ground and access for machinery • Labour intensive • Does not address root system & rapid regrowth
Mechanical Hand Pulling	Plants are hand pulled	Effective if removal occurs prior to seed set, and repeated monitoring ensures that any late germinating plants are addressed	\$0.90-\$50	2	7	\$12.60-\$700	• Health and safety risk with hogweed sap • Labour intensive
Mechanical Taproot Cutting	Plants are cut at the root, 8-10cm below soil surface	Highly effective, will kill the plant. Most effective if applied during the spring	\$0.36-\$50	1-2	7	\$2.52-\$700	• Health and safety risk with hogweed sap • Labour intensive
Cultural Fire	Infestation is burned or heat treated	Does not provide proven effective control	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy as a treatment

a Referenced against Best Management Practices for Giant Hogweed in the Metro Vancouver Region (Metro Vancouver, 2019b).
b Cost information extrapolated from Rajmis et al. (2016), practitioner interviews, Salmon (2020), and information provided by Metro Vancouver. Base costs calculated for targeted grazing using practitioner quotes of \$150-\$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m² of plant material, while maximum grazing costs are from Rajmis et al. (2016). Estimated costs solely reflect treatment costs and do not consider other costs that may be necessary to enable treatment application.

English and Irish Ivies

English (*Hedera helix*) and Irish ivy (*Hedera hibernica*) are two closely related and difficult to differentiate species which will be refer to as 'ivy' throughout the remainder of this report (CABI, 2020b; DiTomaso & Kyser, 2013; Strelau et al., 2018). Introduced from Europe during early colonization, ivy is a common ornamental plant that plays an important role in a multi-million dollar horticultural industry, but also represents a problematic invasive species in both natural and anthropogenically impacted environments across Metro Vancouver (Metro Vancouver, 2019a; Strelau et al., 2018). Ivy spreads vegetatively and by seed, forming dense monocultures in forested areas and climbing trees as a vine, reducing biodiversity and wildlife values of the areas it invades (CABI, 2020a; Ingham, 2008). Preferring moist but well drained soil conditions and direct sunlight, ivy will tolerate a range of light and soil conditions, allowing it to thrive in a wide range of habitats (Strelau et al., 2018).

Efficacy of Targeted Grazing

Targeted grazing is considered an effective control method for ivy despite the mild toxicity associated with the plant (Ingham & Borman, 2010; Strelau et al., 2018). Repeated high-intensity short-duration grazing treatments have been associated with high levels of ivy control, with ivy cover reduced to 4% cover when grazing treatments were repeated over two years, and reduced to 23% cover when grazing occurred for one year only (Ingham & Borman, 2010). In other cases, ivy has disappeared completely from study areas following grazing treatments (Van Uytvanck & Hoffmann, 2009). In addition to reducing ivy cover and biomass, grazing treatments reduce ivy vigour which has an effect ability to regrow and recolonize following grazing treatments (CABI, 2020b).

Grazing removes ivy biomass and disturbs root systems (Ingham, 2008). Ivy has shallow roots and a stoloniferous growth habit. Under grazing treatments root systems are pulled up, and vulnerable meristematic tissues located on stolons are grazed, resulting in high susceptibility to grazing impact, and high levels of treatment efficacy (Ingham & Borman, 2010; Stein & Fosket, 1969; Strelau et al., 2018). Grazing pressure also helps restrict the spread and colonization of ivy into new areas (Metcalfe, 2005). Although targeted grazing is effective in reducing ivy biomass and cover, long-term efficacy is affected by vegetative regrowth capabilities and seed dispersal by birds (Ingham & Borman, 2010; Strelau et al., 2018). Ivy does not have high relative growth rates, and repeated grazing treatments over two years will successfully reduce ivy cover, but ongoing monitoring and follow up treatments are necessary to ensure that recolonization does not occur (Frey & Frick, 1987; Ingham & Borman, 2010; Van Uytvanck & Hoffmann, 2009).

Comparison to Other Control Methods

Ivy control is complicated by reproduction from root fragments, seed dispersal by birds, and a lack of effective chemical control methods (Ahrens & Parker, 2008; CABI, 2020b; Reichard, 2000; Strelau et al., 2018; Waggy, 2010a). All treatments require monitoring plans along with follow-up treatments as needed to prevent ivy recolonization, in conjunction with restoration/revegetation plans (Frey & Frick, 1987; Ingham & Borman, 2010; Van Uytvanck & Hoffmann, 2009).

Biocontrol

Currently there are no biocontrol agents available for ivy, and due to the importance of ivy in the horticultural industry of North America, it is unlikely that biocontrol agents will be developed (Ahrens & Parker, 2008; CABI, 2020b; Reichard, 2000).

Chemical Control

Ivy is tolerant of pre-emergent herbicides, and due to its waxy cuticle there is varied levels of efficacy with the application of post-emergence herbicides, even when surfactants are added (Ingham, 2008; Strelau et al., 2018; Waggy, 2010a; Yang et al., 2013). The highest recorded level of efficacy associated with herbicide application was metsulfuron at 97% control (Yang et al., 2013), although glyphosate, triclopyr, 2,4-D, aminopyralid, and fluroxypyr have all shown varied levels of efficacy (Ahrens & Parker, 2008; Strelau et al., 2018; Waggy, 2010a; Yang et al., 2013). Younger plants are more susceptible to herbicide treatments (CABI, 2020b). Sodium chloride (NaCl) has been shown to damage ivy plants if applied to the shoot, and it is thought that chlorine toxicity is the mode of action (Headley et al., 2019; Strelau et al., 2018). However, NaCl application is not effective when soil-applied, which results in a labour intensive control option (Strelau et al., 2018). Efficacy of other herbicides is increased by the use of surfactants, application during spring, repeated applications, and mechanical injury of vines to allow an entry point for herbicides (Ahrens & Parker, 2008; CABI, 2020b; Soll, 2005; Yang et al., 2013). Use of surfactants can result in damage to non-target native species (CABI, 2020b). Efficacy of chemical control is increased when it is part of an integrated weed management plan (Waggy, 2010a).

Mechanical Control

Mechanical/manual control is an effective treatment for addressing ivy infestations, although it has been noted as labour intensive and costly (Okerman, 2000; Reichard, 2000). The most common form of mechanical control is cutting/pulling of ivy plants, where plants are removed by hand with the assistance of hand tools such as snips, shears, pruners and saws (Ahrens & Parker, 2008; Metro Vancouver, 2019a). One person is able to effectively clear 10 m^2 of ivy each hour if terrain and ivy density are not considerable barriers (Freshwater, 1991). This method is likely to result in ivy root fragments left in/on the soil, which will re-sprout and necessitate continued monitoring and control efforts (Okerman, 2000). Care should be taken to remove as many stem fragments as possible (Strelau et al., 2018). Follow up monitoring and ivy removal treatments are necessary to prevent recolonization (Ahrens & Parker, 2008; Reichard, 2000; Strelau et al., 2018). Additionally waste ivy from mechanical control efforts must be carefully disposed of (piled and burned, or desiccated) to ensure plants don't create new ivy infestations (Ahrens & Parker, 2008; CABI, 2020b).

Cultural Control

Repeated burning (blowtorch) of plants until energy reserves have been exhausted has shown to be an effective, if labour intensive control option (Reichard, 2000; Waggy, 2010a). Heat treatments have shown good control, where ivy leaves are heated enough to destroy cellular structure, but not to the point of burning (Metro Vancouver, 2019a; Waggy, 2010a). Both approaches require considerable care in application and are not feasible options for large infestations.

Control Comparisons

Chemical control is not an effective treatment option due to limited efficacy and restrictions relative to chemical use near watercourses and riparian areas. Mechanical and grazing control options all require repeated treatments both annually over a two-year period, partnered with ongoing monitoring and follow up treatments to address regrowth (Ahrens & Parker, 2008; Okerman, 2000; Reichard, 2000; Strelau et al., 2018).

Metro Vancouver's Best Management Practices for English and Irish ivies (Metro Vancouver, 2019a), currently (as of 2019) recommends cutting/pulling as a mechanical control options, suggests chemical control could be used with caution, and does not recommend grazing/browsing due to concerns over toxicity. However, that guidance was compiled without an extensive review of targeted grazing literature and updating Best Management Practices with information from this feasibility assessment may be a future consideration. Toxicity concerns are addressed in Appendix 2.

English and Irish Ivies Summary

Based on costs and efficacy of treatment (Table 5), it appears that targeted grazing would be more cost effective than mechanical treatments, but less cost effective than chemical treatment. Given that chemical treatment has varied levels of efficacy, mechanical or grazing treatments are recommended. An integrated weed management approach of mechanical control (pulling vines off trees) combined with high intensity targeted grazing over a period of 2 years, with ongoing monitoring and follow up treatments as necessary afterwards is recommended for ivy control. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 5. Summary of control methods for ivy, adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m² per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m²	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • goat grazing • treatment repeated over 2 years • herds trained to ingest ivy	$0.15-$2	1	2	$0.30-$4	• Allows for control of sites with difficult terrain or environmental sensitivities • May result in damage to non-target vegetation • Grazing animals **must** have previous experience with ivy to mitigate toxicity issues
Chemical	Many options for broadcast, spot spraying, or wipe on application	Limited efficacy. Can be improved with surfactants, spring, application, repeated applications, and following mechanical injury of vines to allow entry point	$0.30-$2	1	2	$0.60-$4	• Use only post-emergence herbicides • Not acceptable near watercourses or in riparian areas • Potential for off target impacts, especially if a surfactant is used • Should be combined with other treatments
Mechanical Hand Pulling/Cutting	Plants are pulled/cut by hand	Effective when treatments are repeated as necessary to address regrowth and exhaust root reserves	$0.65-$16	1	2	$1.30-$32.00	• Labour intensive, costly, time consuming • Machinery not applicable - must be done manually
Cultural Fire	Repeated burning of plants and regrowth by blowtorch	Effective if repeated ○ Does not provide effective control as a single treatment	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy as a treatment • Must be repeated until root reserves are exhausted • Labour intensive • Not feasible for large infestations
Cultural Heat Treatment	Ivy leaves are heated enough to destroy cellular structure, but not to the point of burning	Effective if repeated ○ Does not provide effective control as a single treatment	N/A – Likely similar cost to mechanical control at $0.65-$16	1	2	$1.30-$32.00	• Must be repeated until root reserves are exhausted • Labour intensive, potential safety issues • Not feasible for large infestations

a Referenced against Best Management Practices for English and Irish ivies in the Metro Vancouver Region (Metro Vancouver, 2019a).
b Cost information provided by Metro Vancouver, practitioner interviews, Salmon (2020), Ingham (2008), and Soll (2005). Person-hour estimates converted using $50/hr costs and calculated for targeted grazing using practitioner quotes of $150-$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m² of plant material.

Himalayan Balsam

A highly invasive annual species native to the Himalayan region, Himalayan balsam (*Impatiens glandulifera*), was introduced to British Columbia through ship's ballast in the 1930's and has rapidly spread along riparian systems on Vancouver Island, Metro Vancouver, the Fraser Valley, and southeastern British Columbia (CABI, 2020d; Clements et al., 2008; Metro Vancouver, 2019c). An attractive plant, Himalayan balsam prefers moist habitats, often found in riparian areas, fens, woodlands, moist meadows, ditches, and waste areas (CABI, 2020d; Clements et al., 2008). It forms dense, shallow-rooted monocultures with negative impacts on biodiversity. At the end of the season, riparian banks are bare and subject to erosion (CABI, 2020d; Clements et al., 2008). A prolific seed producer, each plant can produce up to 2,500 seeds, which are distributed by exploding seed capsules allowing for rapid spread (Clements et al., 2008; Metro Vancouver, 2019c). Research has indicated that Himalayan balsam has considerable range to expand within the province, and has not yet reached its potential climatic range (Beerling, 1993; Clements et al., 2008).

Efficacy of Targeted Grazing

Himalayan balsam is very susceptible to grazing effects. Grazing has been shown to successfully eliminate infestations, and prevent spread (CABI, 2020d; Clements et al., 2008; Čuda et al., 2017; Larsson & Martinsson, 1998; Pacanoski et al., 2014). The introduction of grazing by cattle, sheep, and horses in pastures with Himalayan balsam has resulted in the complete eradication of the species through consumption and trampling effects (Helmisaari, 2006; Larsson & Martinsson, 1998). Traditional agricultural uses, such as grazing, haying, and cropping, have been shown to prevent the occurrence and spread of Himalayan balsam relative to non-managed areas (CABI, 2020d; Čuda et al., 2017; Petr Pysek & Prach, 1993). Himalayan balsam is unable to establish in continuously grazed or mowed areas with complete cover of grassy species (Larsson & Martinsson, 1998; Petr Pysek & Prach, 1993), and in comparison to non-grazed controls, grazed areas have significantly less occurrence of Himalayan balsam despite favourable conditions and nearby seed sources (Čuda et al., 2017).

Comparison to Other Control Methods

Due to its annual lifecycle and discrete habitat selection, Himalayan balsam control is easier and more effective relative to other invasive plants, however success is dependent on effective timing and repetition of treatments (CABI, 2020d; Clements et al., 2008; Petr Pysek & Prach, 1993). Repeated treatments timed to prevent plants from setting seed are crucial for success. Sadly, 99% control has been found to be as ineffective as no control at all due to the prolific seed production of Himalayan balsam (Wadsworth et al., 2000).

Himalayan balsam seeds remain viable for up to 18 months, and all control treatments should be planned for at least two years in length to ensure complete seed bank eradication (Beerling & Perrins, 1993). Treatments should include a restoration plan to ensure that that vacant spaces left in the plant community following removal of Himalayan balsam aren't colonized by other invasive species (Hulme & Bremner, 2006; Tanner & Gange, 2013). Additionally, upstream populations should be treated first as seeds are transported downstream, and may result in re-infestation if spatial implications are not fully considered (CABI, 2020d; Petr Pysek & Prach, 1993).

Biocontrol

Biocontrol efforts are currently under review, with a promising rust fungus, *Puccinia komarovii var. glanduliferae*, showing efficacy through reduced seedling survival and leaf infection (limiting photosynthetic capacity) on mature Himalayan balsam plants (Tanner et al., 2015; Varia et al., 2016). The rust has efficiently reproduced and completed its lifecycle in the United Kingdom, indicating potential as a treatment in other similar climates (Varia et al., 2016). However, this control option is not yet available.

Chemical Control

Herbicides have high efficacy for control of Himalayan balsam, but use of chemical control options is complicated by restrictions around chemical use in riparian areas, the preferred habitat of Himalayan balsam, and the potential for off target effects on native vegetation growing alongside Himalayan balsam (CABI, 2020d; Clements et al., 2008; Metro Vancouver, 2019c). Chemical control is most effective when applied twice during the growing season, prior to flowering and then again after flowering (Beerling & Perrins, 1993; Pacanoski et al., 2014; Wadsworth et al., 2000). Glyphosate, triclopyr, and 2,4-D amine both provide effective control of Himalayan balsam, but weather conditions may influence efficacy (Beerling & Perrins, 1993; Metro Vancouver, 2019a; Wadsworth et al., 2000). Spraying during flowering is ineffective as it does not prevent the development of viable seed (Beerling & Perrins, 1993).

Mechanical Control

Cutting following flowering and prior to seed set is an effective, but labour intensive control method (CABI, 2020d). Machinery, such as tractors or handheld mowers, can be used to mow Himalayan balsam with high levels of efficacy if mowing occurs prior to seed set and is repeated later in the growing season to ensure that any regrowth does not set seed (CABI, 2020d; Clements et al., 2008; Cockel & Tanner, 2011). This approach is only suitable for flat sites with soil conditions that allow for machinery, it is not appropriate for riparian or moist soils which can be damaged by machinery (CABI, 2020d). Hand cutting is an effective control option that prevents disturbance of sensitive soils (cut below the first node for the best control) but is labour intensive (Clements et al., 2008; Cockel & Tanner, 2011). Management of regrowth is an important consideration when using cutting (either by hand or by machinery) as a control option. The moist environments favoured by Himalayan balsam facilitates regrowth from root systems and set seed in fall is a very real possibility if a repeat treatment does not occur (Clements et al., 2008).

Hand pulling is considered one of the most effective treatments and due to Himalayan balsam's shallow root system does not result in substantial soil disturbance, however timing is an important consideration and pulling must occur prior to seed set (Clements et al., 2008). Spring pulling treatments have been considered effective, where plants can be composted as there are no seeds to manage, and other species can recolonize the treatment location (Cockel & Tanner, 2011). For both forms of mechanical control, cutting and pulling, repeated site visits are recommended every 2 weeks to ensure that regrowth or late germinating plants do not mature and set seed (Beerling & Perrins, 1993).

Cultural Control

Trials using portable propane flamethrowers in the Fraser Valley have shown limited efficacy, and prescribed burning has not been tested (Clements et al., 2008).

Control Comparisons

Chemical control is treatment is only an option on sites that are not near watercourses or riparian areas. Mechanical and grazing control options all require repeated treatments both within the growing season and annually over a two-year period (Beerling & Perrins, 1993; Clements et al., 2008). Livestock are better able to access steep sites relative to mowing machinery and even human volunteers.

Metro Vancouver's Best Management Practices for Himalayan balsam (Metro Vancouver, 2019c), currently (as of 2019) recommends pulling, cutting, and mowing as a mechanical control options, cautions chemical control, and does not recommend grazing. However, that guidance was compiled without an extensive review of targeted grazing literature and updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Himalayan Balsam Summary

Based on costs and efficacy of treatment (Table 6), it appears that targeted grazing may be more cost effective than mechanical or chemical treatment. Chemical treatment is not appropriate in wet Himalayan balsam habitats. To eradicate Himalayan balsam, it is recommended to select upstream populations initially, with targeted grazing and/or mechanical treatments applied twice within the growing season (spring prior to seed set, and late summer) for 2 years, with ongoing monitoring and treatments as required. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 6. Summary of control methods for Himalayan balsam, template adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m^2 per Application [b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m^2	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • sheep and goat grazing • treatment repeated within seasons and over years	\$0.15-\$2	2	2	\$0.60-\$8	• Allows for control of sites with difficult terrain or environmental sensitivities • May result in additional bare soil or erosion issues
Chemical	Broadcast or spot spraying	Highly effective if spraying occurs prior to flowering and is repeated after flowering	\$0.30-\$18	2	2	\$1.20-\$72	• Careful timing is necessary • Requires two applications • High potential for non-target plant impacts • Not acceptable near watercourses or in riparian areas
Mechanical Mowing	Area is mowed or cut multiple times per year for several years	Effective when frequency and duration are sufficient to exhaust seed stock, which is viable for 18 months	\$0.90-\$18	2	2	\$3.60-\$72	• Requires flat ground and adequate access for machinery • Hand cutting is labour intensive
Mechanical Hand Pulling	Plants are pulled up by hand	Highly effective if removal occurs prior to seed set, and repeated monitoring ensures that any late germinating plants are addressed	\$0.90-\$18	2	2	\$3.60-\$72	• Labour intensive, best suited for small populations
Cultural Fire	Infestation is burned	Does not provide effective control	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy as a treatment

a Referenced against Best Management Practices for Himalayan Balsam in the Metro Vancouver Region (Metro Vancouver, 2019c)
b Cost information from Tanner et al. (2008, 2017), practitioner interviews, Salmon (2020), and information provided by Metro Vancouver. Base costs calculated for targeted grazing using practitioner quotes of \$150-\$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m^2 of plant material.

Himalayan Blackberry

Native to Armenia, Himalayan blackberry (*Rubus armeniacus*) is a large perennial shrub that can reach up to 3 meters in height, and has naturalized in many temperate regions of the world (CABI, 2020g; Tirmenstein, 1989). It is a robust sprawling shrub that tolerates a large variety of soil types, textures and pH levels, preferring fertile and well-drained soils (Caplan & Yeakley, 2006; ISCBC, 2019; Tirmenstein, 1989). Reproducing both by seed and vegetatively, it is a highly invasive species that can form near impenetrable copses, resulting in negative impacts to native wildlife and flora (CABI, 2020g). In British Columbia, it is found often in low elevation (<700 m) on disturbed and riparian areas with sun exposure; often along transportation and utility corridors, yards, wetlands, pastures, forest edges, and streambanks (ISCBC, 2019; Metro Vancouver, 2019d; Pojar & MacKinnon, 2004). Located across the Lower Mainland, it is widespread within the Metro Vancouver region (Metro Vancouver, 2019d).

Efficacy of Targeted Grazing

Targeted grazing is a common management method for control of Himalayan blackberry in Australia and New Zealand. Both countries have implemented large-scale integrated weed management programs that heavily utilize targeted grazing by sheep and goats for blackberry control (DiTomaso & Kyser, 2013; Meat & Livestock Australia, 2007). Livestock, specifically goats and sheep, are able to access slopes and terrain inaccessible to machinery; this includes the steep slopes that Himalayan blackberry colonizes in the Metro Vancouver region (Metro Vancouver, 2019d; Soll, 2004). Successful reductions in the size of Himalayan blackberry infestations have been found across several studies, with a commonality of increased efficacy with higher intensity treatments repeated both within season and across years (Chow, 2018; Ingham, 2014; Krueger et al., 2014; Magadlela et al., 1995; McGregor, 1996; Milliman, 1999). Although complete eradication of blackberry through targeted grazing has not been found often throughout the literature, high levels of control have been noted, including cover reductions from 95% to 24% cover over two years of treatment (Ingham, 2014), and volume reductions decreasing from >700 m^3 to 3 m^3 over one year of treatment (McGregor, 1996).

Successful suppression of blackberry spread and/or regrowth through application of targeted grazing has been noted across studies, with drastic reductions in daughter plants (first year canes rooting at tips and propagating) of up to 100% associated with grazing treatments (Amor, 1974; Hoshovsky, 2000; Milliman, 1999). Higher intensity and repeated grazing treatments are associated with better suppression of regrowth or spread (Milliman, 1999).

Treatment efficacy is influenced by the vigorous vegetative regrowth capabilities of blackberry (Ingham, 2008). The plant grows rapidly, with canes maturing and becoming woody quickly, providing protection to new growth within the thickets (Milliman, 1999). Repeated grazing treatments for three to five growing seasons is necessary for the successful reduction of blackberry cover, with repeated defoliations resulting in the depletion of root reserves, resulting in a lack of resources available for regrowth (Chow, 2018; Ingham, 2014; Milliman, 1999).

Control Method Comparison

The efficacy of control methods for Himalayan blackberry is affected by aggressive vegetative growth following biomass removal, and varied responses to chemical control methods (Ingham, 2008). Amor (1974) found a maximum growth rate of 0.404 g/day for blackberry primocanes (first year canes), a rapid growth rate more reflective of herbaceous plants than woody plants such as Himalayan blackberry. Seeds remain viable for several years, but the specific length of viability has not been determined for Himalayan blackberry (Gaire et al., 2015). All treatments are generally considered ineffective unless repeated seasonally and/or annually, and/or used in combination with other complimentary treatments (Bennett, 2006; CRC Weed Management, 2003; Soll, 2004).

Biocontrol

The potential for off-target damage to commercially grown *Rubus* species (commercial raspberries and blackberries) has precluded the advancement of classic insect biological control agents (ISCBC, 2019).

Chemical Control

Chemical control works best when canes are first removed mechanically, and chemicals are used to treat tender regrowth (Amor, 1974; Gaire et al., 2015; Prather et al., 2011; Soll, 2004). Broadcast spraying of triclopyr, glyphosate, metsulfuron, dicamba, imazapyr, picloram, or a 2-4D triclopyr mixture can be effective, but requires additional work to mechanically remove canes prior to and/or after treatment allow for increased efficacy and restoration success (Metro Vancouver, 2019d; Prather et al., 2011; Soll, 2004). Timing of application is an important consideration, where fall application results in greater translocation to roots and increased efficacy relative to application during the growing season. Growing season application results in the transport of herbicide upwards with phloem sap, resulting in non-effective top-kill (Bennett, 2006). Efficacy of chemical control is increased through combination with other methods, such as burning, grazing, or mechanical treatments; to manage regrowth (Gaire et al., 2015). Chemical control is complicated by restrictions around chemical use in riparian areas, one of the preferred habitats of Himalayan blackberry (Gaire et al., 2015; Pojar & MacKinnon, 2004).

Mechanical Control

Repeated mowing is an effective treatment as it is non selective and eliminates all above ground biomass, although it has been cautioned as 'labour intensive and often painful' (Gaire et al., 2015). Not surprisingly, treatments must be several years in length and occur multiple times per year to be effective (Ingham, 2008). Hand pulling is considered quite effective, but is only practical for small populations, and must be carefully undertaken to ensure that canes, roots, and root crowns are all removed to ensure that re-sprouting does not occur (CRC Weed Management, 2003; DiTomaso & Kyser, 2013; Gaire et al., 2015). Soll (2004) noted that one acre of land heavily infested by Himalayan blackberry will require between 300-1,000 volunteer hours to effectively clear. Bulldozing results in heavy re-sprouting, and spreads root fragments and stems, often resulting in blackberry spread (CRC Weed Management, 2003; DiTomaso & Kyser, 2013). Some literature notes that 'scalping' using bulldozers may be effective if crowns and the majority of roots are dug out, but it must include a raking treatment that pulls out roots to dry in the sun and die, or to pile and burn (CRC Weed Management, 2003). However, follow up treatment is still required. Stringent sanitation measures are suggested following mechanical control to prevent regrowth and landfill contamination, such as wrapping cut plants in bags or tarps (Gaire et al., 2015). It is also cautioned that removal during nesting season may have negative impacts on some bird species (Bennett, 2006).

Cultural Control

Prescribed burning will not provide effective control as a treatment itself as plants re-sprout from root crowns, but can be used in combination with other treatments as part of an integrated weed management treatment program (Bennett, 2006; Soll, 2004). Long-term control has been found when burning is followed by herbicide treatment on re-sprouting plants, or additional burning or cutting to deplete root reserves and reduce the available seed bank, followed by restoration efforts to recolonize the site (Soll, 2004).

Shading can be used to supress blackberry infestations, but this requires deep shade from a closed canopy and ongoing mechanical upkeep along the edges and on trees as they grow (Metro Vancouver, 2019d). This method is only an option where forest is a desired outcome.

Control Comparisons

In the early 1990's Magadlela et al. (1995) estimated brush control (heavily composed of blackberry) costs in West Virginia at $33/ha for goats, $262/ha for sheep, mechanical cutting at $133/ha, and herbicide control at $593/ha, and noted that goat grazing was the most cost effective and rapid control method. In the Pacific Northwest chemical control costs have been estimated at $250-$300 USD/acre, mechanical tractor clearing at $250-$500 USD/acre, and hand clearing at >$1,000 USD/acre (Soll, 2004).

Eradication guidelines from Australia (Meat & Livestock Australia, 2007) provide the following integrated weed management strategies for Himalayan blackberry:

Eradication over several years:

1. Cut access tracks into infestation
2. Apply goat grazing in early spring (stocking of up to 30 goats/ha recommended)
3. Burn canes in late summer
4. Spot spray inaccessible plants
5. Reseed and fertilize burnt area

Rapid eradication (1 year):

1. Cut access tracks into infestation
2. Apply goat grazing in early spring (stocking of up to 50 goats/ha recommended)
3. Burn canes in late summer
4. Spray all crowns
5. Reseed and fertilize burnt area

Metro Vancouver's Best Management Practices for Himalayan Blackberry (Metro Vancouver, 2019d), recommends pulling, cutting, digging/grubbing, tilling, and mowing as a mechanical control options. The document also recommends chemical control and partially recommends cultural control (shading and grazing). Updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Himalayan Blackberry Summary

Based on costs and efficacy of treatment (Table 7), it appears that targeted grazing may be as cost effective as mechanical hand treatments, but less cost effective than chemical or mowing treatments. Treatment costs and efficacy vary significantly depending on skill of practitioner. Efficacy is highly dependent on repeated treatments to fully address infestation scope. For effective control, an integrated weed management approach is recommended, comprised of high intensity grazing treatments or mechanical control repeated at least twice within the growing season (spring and summer), repeated for 3-5 years with ongoing monitoring and treatments as required. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 7. Summary of control methods for Himalayan blackberry, adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m2 per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m^2	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • goat grazing • access tracks cut into infestation • mechanical treatment prior to goat grazing • treatment repeated within seasons and over years	\$0.15-\$2	2	3-5	\$0.90-\$20	• Allows for control of sites with difficult terrain or environmental sensitivities • May result in damage to non-target vegetation
Chemical	Broadcast or spot spraying	• Works best when canes are first removed mechanically, and chemicals treat regrowth • Fall application is more effective than spring/summer • Variability in efficacy has been noted	\$0.30-\$2	1	2-4	\$0.60-\$8	• Combine with mechanical to remove canes first, and then herbicide • Careful selection of herbicides and timing of application required • Not acceptable near watercourses or in riparian areas
Mechanical Mowing	Multiple times per year for several years	Effective when frequency and duration are sufficient to exhaust root reserves	\$0.13-\$0.50	2-4	3-5	\$0.78-\$10	• Requires flat ground and adequate access
Mechanical Hand Pulling	Roots and crowns dug up by hand	Very effective if removal is thorough and no root fragments are left	\$0.30-\$12	2	3-5	\$1.80-\$120	• Significant soil disturbance • Labour intensive
Mechanical Bulldozing	Above ground vegetation and soil layer containing roots and crowns are removed	• Need complete removal of roots and crowns • It is very difficult to fully remove all root fragments, raking treatment to remove roots may increase efficacy	\$0.30-\$1.22	1	3-5	\$0.90-\$6.10	• Results in re-sprouting, spread of root fragments and stems • May result in spread of infestation • Soil disturbance • Labour intensive
Cultural Fire	Infestation is burned	Not effective due to re-sprouting	N/A	N/A	N/A	N/A	Safety concerns and lack of efficacy

a Referenced against Best Management Practices for Himalayan Blackberry in the Metro Vancouver Region (Metro Vancouver, 2019d).
b Cost information from Bennett (2006), Magadlela et al. (1995), Soll (2004), practitioner interviews, Salmon (2020), and information provided by Metro Vancouver. Grazing costs also used practitioner quotes of \$150-\$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m^2 of plant material.

Purple Loosestrife

A tall and attractive perennial, purple loosestrife (*Lythrum salicaria*) is native to most of Europe save the most northerly portions, and is highly invasive in wetland areas in much of North America (CABI, 2020e; Mal et al., 1992; Munger, 2002). Purple loosestrife has an extensive persistent woody rootstock with large nutrient reserves, which is paired with extremely high seed output of up to 2,700,000 viable seeds per plant. Additionally, the ability to reproduce from root fragments, an affinity for disturbed habitats, and no natural limiting predators in North America, results in a highly invasive and persistent plant (CABI, 2020e; Invasive Species Council of BC, 2017a; Mal et al., 1992; Munger, 2002; Scott & Robbins, 2006; Thompson et al., 1987).

Purple loosestrife is widespread across Metro Vancouver, found primarily in moist natural areas such as lakes, wetlands, marshes, ditches, and along riversides (Metro Vancouver, 2020a). In its native range, purple loosestrife is found in a much wider variety of habitats, with the exception of very dry areas (CABI, 2020e). This represents a potential for increased spread across the Metro Vancouver region as the plant becomes increasingly established (Invasive Species Council of BC, 2017a).

Efficacy of Targeted Grazing

Although targeted grazing may not jump to mind immediately as a control treatment for purple loosestrife due to the potential negative impacts of grazing in riparian/moist areas, grazing has been used to reduce loosestrife infestations and has been linked with the suppression/prevention of loosestrife invasion, likely linked to effective grazing pressure in intermittently moist locations where grazing pressure is more likely to occur (Kleppel & LaBarge, 2011; Tesauro, 2001; Tesauro & Ehrenfeld, 2007). Although there are not a large number of studies exploring the impact of grazing on purple loosestrife, in the reported studies there have been significant reductions in purple loosestrife abundance (>40% decline in cover) and vigour (plants did not flower and were half as tall as non-grazed comparisons) following grazing treatments (Kleppel & LaBarge, 2011; Tesauro, 2001; Tesauro & Ehrenfeld, 2007). Control efficacy was associated with both grazing effect and trampling effects, where grazing animals fragmented loosestrife rootstock, reducing energy reserves and the ability for plants to regrow (Kleppel & LaBarge, 2011; Tesauro, 2001).

Targeted grazing treatments fragment loosestrife stands, allowing other plant species to establish, increasing species richness/diversity, and enhancing habitat for wildlife (Kleppel & LaBarge, 2011; Tesauro, 2001). Grazing is also associated with suppressing and preventing loosestrife spread, with reduced loosestrife abundance and density noted in wetland pastures that have seasonal grazing pressure when compared to adjacent non-grazed areas (Tesauro, 2001).

Control Method Comparison

Purple loosestrife control is complicated by an extensive and nutrient rich rootstock, reproduction from root fragments, and extremely high seed output (CABI, 2020e; Invasive Species Council of BC, 2017a; Mal et al., 1992; Munger, 2002; Scott & Robbins, 2006; Thompson et al., 1987). All treatments are generally considered ineffective unless repeated and used in combination with other complimentary treatments. Purple loosestrife seeds remain viable for at least 3 years, and all control treatments should consider the robust seed bank implications to ensure eradication (Munger, 2002; Welling & Becker, 1990). Upstream populations should be treated first as seeds are transported downstream, and may result in re-infestation (Thompson et al., 1987).

Biocontrol

There are a number of biocontrol agents available for purple loosestrife control, with *Neogalerucella calmariensis* and *Neogalerucella pusilla* associated with effective biocontrol in the Metro Vancouver region (Metro Vancouver, 2020a), and two specific defoliators (*Galerucella calmariensis* and *Hylobius transversovittatu*) being part of successful biocontrol trials in Canada (Reinbrecht, 2017). Control of up to 95% has been found in some trials, while others have noted no significant impact with varied biocontrol species (Blossey et al., 2001; Grevstad, 2006; Metro Vancouver, 2020a). Biocontrol can be a viable option when infestations are large in size and eradication is not immediately necessary (Metro Vancouver, 2020a).

Chemical Control

Several herbicides have shown effective (>90%) control of purple loosestrife, but chemical control is complicated by restrictions relative to chemical use in riparian areas, which is loosestrife's primary habitat in Metro Vancouver (CABI, 2020e; Metro Vancouver, 2020a; Munger, 2002). There is also a high potential for off target effects on native vegetation, which may result in monocultures of purple loosestrife due to re-establishment from the robust seed bank (Munger, 2002; Welling & Becker, 1990). Application during late flowering is the most effective, and multiple applications annually are necessary for successful eradication (Knezevic et al., 2018; Malecki & Rawinski, 1985). Glyphosate, dicamba, 2,4-D, triclopyr, metsulfuron, and Imazapyr have all shown proven control of purple loosestrife. Triclopyr has been less effective; while glyphosate has shown the highest levels of control (Knezevic et al., 2018; Malecki & Rawinski, 1985; Munger, 2002).

Mechanical Control

All mechanical control efforts show the highest levels of efficacy when applied prior to seed set (Invasive Species Council of BC, 2017a). Hand pulling is an effective control treatment, but is labour intensive and requires careful attention to ensure the rootstock is completely removed, and care must be taken to minimize soil disturbance (Mal et al., 1992). Hand pulling is likely not feasible for larger infestations. Pulled plants should be bagged and disposed of or burned on site to mitigate potential seed spread (Munger, 2002; Reinbrecht, 2017). Cutting has resulted in reduced shoots and seed production of purple loosestrife infestations, with higher efficacy associated with late summer treatments (Malecki & Rawinski, 1985). However, cutting is ineffective in reducing loosestrife infestations due to aggressive re-sprouting from rootstock (Mal et al., 1992; Munger, 2002; Scott & Robbins, 2006; Thompson et al., 1987). Mechanical cutting is associated with the spread of purple loosestrife due to its ability to grow from root fragments (Invasive Species Council of BC, 2017a). Seed head clipping can prevent seed release and dispersal, but does not provide effective control of existing infestations (Invasive Species Council of BC, 2017a).

Cultural Control

Burning is not an effective control measure owing to moist soils and extensive regrowth of rootstock (Louis-Marie, 1944; Mal et al., 1992; Thompson et al., 1987). Direct application of flame has been associated with low mortality and limited efficacy, is not cost effective, and represents safety risks (Mal et al., 1992; Thompson et al., 1987). Flooding has been purported as an effective control treatment, with the reduction of loosestrife abundance associated with longer term (5-8 week) flooding of 0.3-0.5 m (Clay, 1986; Malecki et al., 1993; Thompson et al., 1987). Other studies note that success is limited, and the treatment is associated with negative impacts on emergent riparian vegetation and endemic natural vegetation (Mal et al., 1992; Malecki et al., 1993). Flooding is overall considered non-effective and not recommended.

Control Comparisons

Chemical control is a site-specific option due to restrictions around chemical use in watercourses and riparian areas. Mechanical and grazing control options all require repeated treatments both within the growing season and on an annual basis (Malecki & Rawinski, 1985; Thompson et al., 1987; Woo et al., 2002). Biocontrol is a good option if *Neogalerucella calmariensis* or *Neogalerucella pusilla* are available and eradication is not immediately necessary. All treatments require ongoing monitoring plans, and consistent application of follow-up treatments in conjunction with restoration/revegetation plans. Success is dependent a long-term integrated management plan that focuses on consistency in application to exhaust root reserves and diligently manage regrowth (Woo et al., 2002).

Metro Vancouver's Best Management Practices for purple loosestrife (Metro Vancouver, 2020a), recommends biological control (all available agents were noted), pulling or digging as a mechanical control option, cautions chemical control, and does not currently recommend cultural control (burning, flooding, or grazing). However, that guidance was compiled without an extensive review of targeted grazing literature and updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Purple Loosestrife Summary

Based on costs and efficacy of treatment (Table 8), it appears that targeted grazing may be more cost effective than mechanical hand treatments, but less cost effective than chemical or mowing treatments, however chemical treatments are not suitable for the majority of purple loosestrife habitats (aquatic). Grazing may not be compatible with purple loosestrife habitat and may be difficult to implement with goats due as they do not like to have wet feet. Cost information was not available for biocontrol, but efficacy appears high in some instances.

An integrated weed management approach is recommended for purple loosestrife control, with mechanical (hand pulling) treatments combined with grazing treatments (if possible), both applied with as much frequency is opportunistically possible within each growing season over 3 years ensuring that plants never set seed, in combination with biocontrol agents, and ongoing monitoring and treatments as required. Once three years have passed it is necessary to determine if rootstocks have been fully exhausted and whether vegetative reproduction may occur, if so, additional treatments must occur to fully exhaust rootstock. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 8. Summary of control methods for purple loosestrife, template adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m^2 per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m^2	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Moderate-Low. Higher efficacy associated with: • summer treatment • long-term application of grazing	$0.15-$2	1-4	3	$0.45-$24	• Grazing on moist and saturated soils can result in the reduction of plant cover, soil compaction, erosion, degradation of aquatic habitat, and soil hummocking
Biocontrol	Classical biocontrol insects	Varied efficacy	Highly variable	N/A	N/A	N/A	• Varied levels of success • Long-term control option
Chemical	Broadcast or spot spraying	Effective if applied during late flowering, and with multiple applications	$0.30-$2	2-4	2-4	$1.20-$32	• Not acceptable near watercourses or in riparian areas
Mechanical Mowing	Area is mowed	Reduces shoots and seed production, does not effectively reduce infestations	$0.13-$0.50	2-4	2-4	$0.52-$8	• Risk of spread of purple loosestrife from vegetative re-sprouting • Labour intensive • Does not address root system, regrowth occurs
Mechanical Hand Pulling	Plants are pulled up by hand	Effective if removal occurs prior to seed set, and repeated monitoring ensures that any regrowth is pulled	$0.30-$12	2-4	2-4	$1.20-$192	• Labour intensive • May result in substantial soil disturbance • Long-term monitoring is necessary
Mechanical Hand Cutting	Plants are cut by hand	• May be effective when frequency and duration are sufficient to exhaust root reserves and seed stock. • Has been ineffective in past studies due to regrowth	$0.30-$12	2-4	2-4	$1.20-$192	• Labour intensive • Long-term monitoring is necessary
Cultural Fire	Infestation is burned	Does not provide proven effective control	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy as a treatment
Cultural Flooding	Treatment area is flooded to a depth of 0.3-0.5m	Varied efficacy across studies, some note high success some note limited success	N/A	N/A	N/A	N/A	• Negative impacts on native vegetation • Difficult logistics • Varied efficacy

a Referenced against Best Management Practices for Purple Loosestrife in the Metro Vancouver Region (Metro Vancouver, 2020a).
b Control option costs extrapolated and estimated based on information provided by Metro Vancouver, practitioner interviews, and Salmon (2020). Grazing costs calculated using practitioner quotes of $150-$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m^2 of plant material.

Scotch Broom

A large, long-lived bushy shrub, Scotch broom (*Cytisus scoparius*) is native to northern Africa and parts of Europe, and was introduced to North America both as an ornamental and unintentionally in discarded ship ballast (CABI, 2020a; Peterson & Prasad, 1998; Zouhar, 2005). It rapidly invades disturbed areas where it grows as a dense monoculture, and has nitrogen fixing abilities which allow it to thrive in low-quality soils (CABI, 2020a; Peterson & Prasad, 1998; Zouhar, 2005). It is a highly successful invader due to stem photosynthesis, prolific seed production, a long-lived seed bank, nitrogen fixing abilities, tolerance for a wide range of habitats, an ability to re-sprout from stumps and/or root crowns, and an aptitude for establishment and persistence following disturbance (Bellingham & Coomes, 2003; CABI, 2020a; Peterson & Prasad, 1998; Zouhar, 2005). Seeds remain viable for up to 30 years in the soil, and seed counts can reach >4,000 per m^2 in the seed bank (Peterson & Prasad, 1998; Smith & Harlen, 1991).

Scotch broom commonly occurs throughout the Metro Vancouver region, it can grow in a wide range of habitats is most commonly found in disturbed soils along transportation corridors, gravel pits, utility rights of way, and degraded pastures (King County, 2008; Metro Vancouver, 2019f; Peterson & Prasad, 1998).

Efficacy of Targeted Grazing

Targeted grazing is associated with suppression and reduction of Scotch broom infestations. Grazing animals will tend to select for the tops of young plants and any regrowth, reducing root reserves and preventing seed set and subsequent spread of Scotch broom if grazing treatments are regularly applied and sustained (King County, 2008; Pontes et al., 2016). High intensity browsing results in high levels of Scotch broom mortality, while light intensity browsing still greatly reduces reproductive output (Pontes et al., 2016). Grazing treatments have successfully suppressed spread of Scotch broom, both through reductions in reproductive output and through grazing/trampling of seedlings (Álvarez-Martínez et al., 2016; Bellingham & Coomes, 2003; Pontes et al., 2016). Grazing has resulted in significant (48%) seedling mortality, and reduced height and growth suppression of surviving seedlings (Álvarez-Martínez et al., 2016; Bellingham & Coomes, 2003; Pontes et al., 2016). Low densities of Scotch broom (<10% cover) show greater impact from grazing treatments than denser infestations (Zouhar, 2005). Grazing treatments are most effective when used on younger plants (1-4 years old) or on regrowth, but are less effective on mature stands (King County, 2008; Pontes et al., 2016). An initial cutting/mowing treatment with follow-up grazing treatments an effective approach, and if this is not practical access paths should be cut through the infestation to allow for livestock access (Meat & Livestock Australia, 2007).

Grazing as the sole treatment option is not associated with full eradication of Scotch broom, but is effective when applied in combination with other treatments as part of a larger integrated weed management plan (Álvarez-Martínez et al., 2016).

Control Method Comparison

Scotch broom control efficacy is complicated by its vigorous regrowth capabilities, nitrogen fixing properties that allow it to out-compete native vegetation in marginal soils, prolific production of highly viable seeds creating a long-lived seed bank, and an ability to colonize and thrive in disturbed areas (Bellingham & Coomes, 2003; CABI, 2020a; Peterson & Prasad, 1998; Smith & Harlen, 1991; Zouhar, 2005). All treatments are generally considered ineffective unless repeated and used in combination with other complimentary treatments.

Biocontrol

Although there are several effective biocontrol agents for Scotch broom, none are currently available in British Columbia (Invasive Species Council of British Columbia, 2014). Biocontrol agents are generally slow to establish (5-7 years) and are only effective as a component of an integrated weed management plan (King County, 2008; Metro Vancouver, 2019f).

Chemical Control

Effective in providing initial control of new Scotch broom infestations, chemical control rates vary between 50-100% dependent on the chemical chosen and climatic conditions/timing of application (CABI, 2020a; Hosking et al., 1998). However, chemical control is not successful on its own in controlling Scotch broom, which will fully regenerate from the seed bank following herbicide application if ongoing monitoring and repeat spraying does not occur (CABI, 2020a; Pascoe et al., 2014; Zouhar, 2005). Chemical control can occur through foliar application, injection of stem bases, or by 'painting' Scotch broom stumps with herbicide following cutting to prevent regrowth (CABI, 2020a; Peterson & Prasad, 1998). Effective herbicides that provide greater than 80% control of Scotch broom include glyphosate, metsulfuron-methyl, picloram, triclopyr combined with 2,4-D, imazapyr, and fluroxypyr (CABI, 2020a; Hosking et al., 1998; Peterson & Prasad, 1998; Zouhar, 2005). Herbicides should be applied in the spring during active growth, following leaf flush but prior to flowering (Graves et al., 2010; Zouhar, 2005). Broadcast applications have a high potential for non-target impacts (Peterson & Prasad, 1998). Chemical control is considered a temporary control method as it does not fully address the seed bank and the conditions that initially enabled Scotch broom infestations (Zouhar, 2005). Studies have shown that although herbicide control initially reduces Scotch broom cover; cover returns to original levels within 3 years with no successive treatments (Pascoe et al., 2014). It can be an effective component of an integrated weed management strategy but must be considered within that context and not as a stand-alone treatment.

Mechanical Control

All mechanical control treatments must include an ongoing monitoring plan with consistent follow up treatments as Scotch broom seedlings will continue to establish from the seed bank for up to 30 years (Peterson & Prasad, 1998; Smith & Harlen, 1991; Zouhar, 2005). For the highest level of efficacy mechanical control treatments should occur during periods of moisture stress to prevent re-sprouting (Peterson & Prasad, 1998; Ussery & Krannitz, 1998; Zouhar, 2005). Hand pulling is effective in removing whole plants and reducing re-sprouting, but is a labour intensive control method that is not practical for larger infestations (Peterson & Prasad, 1998; Ussery & Krannitz, 1998). Hand pulling is best practiced after rainfall when soil is moist and loose, allowing for a more complete removal of the root system and reducing the potential of re-sprouting, and should occur prior to seed production (Peterson & Prasad, 1998; Zouhar, 2005). Pulling often results in soil disturbance, which may trigger germination of broom seeds in the seed bank, and results in damage to desirable plant species, with significantly more trampling of native species associated with hand pulling relative to cutting (Ussery & Krannitz, 1998; Zouhar, 2005). Hand cutting Scotch broom plants at ground level at the end of summer during dry periods is effective and results in low re-sprouting rates (3-9%) based on a study in British Columbia (Ussery & Krannitz, 1998). Other studies have found that approximately half of treated plants should be expected to re-sprout following cutting treatments (Zouhar, 2005). Cutting should occur during the driest part of the year when plant reserves are at their lowest to minimize the ability of plants to re-sprout (Prasad, 2003). Mowing is not as effective as hand cutting or pulling, and must be repeated throughout the growing season or used in combination with other control treatments to be effective (King County, 2008). In general, mechanical control using machinery has been found to promote germination from the seed bank, with slashing and cultivation and bulldozing all noted to be counterproductive, resulting in increased germination and potentially spreading seed to new areas on machinery (Hosking et al., 1998; Parker et al., 2017; Peterson & Prasad, 1998). Mechanical treatments are also less selective and more likely to damage non-target vegetation, and have limitations on the topography that they can be used on (Peterson & Prasad, 1998; Zouhar, 2005). Mulching has shown better efficacy than other mechanical treatments as it provides a layer of mulch limiting broom regeneration for the short-term, but does require stringent and ongoing monitoring and follow up treatments to be effective (Talbot, 2000).

Cultural Control

Shading can suppress Scotch broom, and growing a closed tree canopy may be a long-term control option in areas where it is desired and appropriate (Grove et al., 2017; Metro Vancouver, 2019f). Scotch broom plants must be quite dry to enable an effective burn, otherwise the plants are simply top-killed and will re-sprout without dying (Downey, 2000; Zouhar, 2005). Fire rarely achieves mortality of existing Scotch broom plants due to the risks around using fire treatments. Fire is a problematic option in that it creates conditions well-suited for re-invasion by Scotch broom, such as heat stimulating germination of seeds from the seed bank, and the creation of bare soil which supports broom colonization (CABI, 2020a; Downey, 2000; MacDougall, 2002). Although hot fires can reduce seed banks to less than 10% cover, Scotch broom appears to be adapted to post-fire conditions and fire treatments are generally followed by increases in broom cover with high seedling survival due to reduced competition from other plants removed during fire treatments (Downey, 2000; MacDougall, 2002). Heat-girdling the lower stems of Scotch broom using a flamer can be an effective spot treatment to eradicate mature plants, however it is labour intensive and does not address seed bank issues (Woo et al., 2004).

Control Comparisons

Cultural controls are not overly effective and may cause increases in infestations (Downey, 2000; MacDougall, 2002). Chemical, mechanical, and grazing control options all have varied levels of efficacy, and most importantly all require ongoing monitoring plans, and consistent application of follow-up treatments in conjunction with restoration/revegetation plans. Success is dependent a long-term integrated management plan that focuses on consistency in application to manage regrowth and address the substantial and long-lived seed bank of Scotch broom (Peterson & Prasad, 1998; Isa Woo et al., 2004).

Eradication guidelines from Australia (Meat & Livestock Australia, 2007) provide the following integrated weed management strategy for effective eradication and ongoing control of Scotch broom:

1. Cut access tracks
2. Apply goat grazing in early spring (stocking of up to 30 goats/ha recommended) for two years
3. Treat with herbicide, burn 2 months following herbicide application
4. Repeat herbicide application and burn treatment the following year
5. Mechanically knock down old stems
6. Reseed and fertilize
7. Maintain low goat stocking for ongoing control on an annual basis

Metro Vancouver's Best Management Practices for Scotch Broom (Metro Vancouver, 2019f), recommends pulling, cutting, and mowing as manual/mechanical control. The document also recommends chemical control, and partially recommends cultural control (shading and grazing). Updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Scotch Broom Summary

Based on costs and efficacy of treatment (Table 9), it appears that targeted grazing is not cost effective compared to mechanical hand treatments and chemical treatments. For effective control of Scotch broom, an integrated weed management approach is recommended, comprised of initial chemical control, followed by hand pulling to remove existing plants, or mowing if plants are too large to pull out. Mechanical treatments should be repeated within seasons, with chemical control repeated on an annual basis. Ongoing monitoring and consistent follow up treatments are necessary as Scotch broom seedlings will continue to establish from the seed bank for up to 30 years (Peterson & Prasad, 1998; Smith & Harlen, 1991; Zouhar, 2005).

Table 9. Summary of control methods for Scotch broom, template adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m^2 per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m^2	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • sheep and goat grazing • treatment continuous during active growth periods and repeated annually over many years • treatment applied to smaller plants and regrowth • high densities of grazing animals • A mechanical cut occurs prior to grazing	$0.15-$2	1 Continuous (Estimated at 30 days)	4-30	$18-$1,800	• Good on sites with difficult terrain or environmental sensitivities • Ensuring other plants are available for grazing will reduce potential health impacts on animals from toxic compounds • Some seeds remain viable (8%) after digestion • Impacts on non-target plants will occur
Chemical	Broadcast, spot spraying, stem injection, or painting stumps	• Effective for initial control of infestation (50-100% mortality) • Apply in spring during active growth prior to flowering	$0.03-$2	1	3-5	$0.09-$10	• Requires multiple applications • High potential for non-target plant impacts • Not acceptable near watercourses or in riparian • Considered temporary control – does not address seed bank
Mechanical Mowing	Area is mowed or cut multiple times per year for several years	• Effective when frequency and duration are sufficient to exhaust seed stock (30+ years) • Considered less effective than pulling or hand cutting	$0.50-$2	2-4	1-30	$1-$240	• Requires flat ground and adequate access for machinery • Labour intensive • Does not address root system, rapid regrowth occurs necessitating repeated treatments during growing season • Damages non-target vegetation • Promotes germination of seeds from seed bank
Mechanical Tilling	Area is tilled with machinery	Not effective, associated with increased cover and spread	$0.10-$2	1	1-30	$0.10-$60	• Requires flat ground and access for machinery • Labour intensive

Treatment	Summary	Efficacy	Estimated Cost per m² per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m²	Considerations
							• Promotes re-sprouting and germination of seed bank • Damages non-target vegetation
Mechanical Mulching	Area is mulched	More effective than tilling or mowing, less than pulling or hand cutting Layer of mulch provides short-term limitation of broom regeneration	$0.07	1	1-30	$0.07-$21	• Requires flat ground and access for machinery • Labour intensive • Promotes re-sprouting and germination of seed bank • Damages non-target vegetation
Mechanical Hand Pulling	Plants are pulled up by hand	Effective if removal occurs when soil is moist to remove root systems more fully	$0.65	1	1-30	$0.65-$19.50	• Labour intensive • Soil disturbance which may trigger germination • Damages native plants
Mechanical Hand Cutting	Plants are cut at soil surface	• Effective with low re-sprouting rates • Most effective during the driest part of the year when plants have lowest levels of reserves	$0.65	1	1-30	$0.65-$19.5	• Labour intensive
Cultural Fire	Infestation is burned or heat treated	• Not a proven effective control • Increases Scotch broom post-fire	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy
Cultural Shade	A closed tree canopy is grown in area	• Some efficacy over the long-term	N/A	N/A	N/A	N/A	• Long-term (>30 year) option • Limited efficacy • Represents significant land use change

a Referenced against Best Management Practices for Scotch Broom in the Metro Vancouver Region (Metro Vancouver, 2019f).

b Control option costs extrapolated and estimated based on information from Álvarez-Martínez et al. (2016), CABI (2020a), Talbot (2000), Frid et al. (2009), practitioner interviews, Salmon (2020), and data provided by Metro Vancouver. Grazing costs calculated using practitioner quotes of $150-$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m² of plant material

Wild Chervil

Wild chervil is a short-lived herbaceous perennial, biennial, and in some cases annual, reaching heights of up to 1.5 m, with a thick tap root up to 2 m in length (Darbyshire et al., 1999; van Mierlo & van Groenendael, 1991). With small white flowers borne in an umbel, wild chervil is a prolific seed producer, producing 800-10,000 short-lived seeds (1-2 years viable) in late summer, in addition to vegetative reproduction from root crowns (Darbyshire et al., 1999). Wild chervil is often associated with disturbed habitats, and in Metro Vancouver is found along railway and road corridors and in ditches (Darbyshire et al., 1999; Metro Vancouver, 2020b). Through aggressive vegetative reproduction, wild chervil will grow to the exclusion of other forms of vegetation and form monocultures (Darbyshire et al., 1999).

Efficacy of Targeted Grazing

The presence of grazing animals has long been associated with reduced abundance of wild chervil relative to adjacent non-grazed areas, or when comparing the same pasture between grazed vs. non-grazed years Darbyshire et al., 1999; DiTomaso & Kyser, 2013; Hansson & Persson, 1994; Hellström et al., 2003; Wagner, 1967). Wild chervil will not establish in grazed areas even when it has successfully colonized adjacent non-grazed areas (Darbyshire et al., 1999; DiTomaso & Kyser, 2013; Hansson & Persson, 1994; Hellström et al., 2003; Wagner, 1967). A study reviewing the effect of grazing treatments noted that wild chervil was more abundant in ungrazed treatments relative to grazing or cutting treatments (Pavlů et al., 2007). However, other studies have noted that grazing has not had a significant effect on wild chervil abundance (Hellström et al., 2003). In addition to grazing effects, wild chervil does not easily tolerate trampling effects, which provides an additional measure of control and suppression in grazed pastures (Grime et al., 1988).

Control Method Comparison

Wild chervil control is complicated by large, nutrient rich taproots that support vegetative reproduction, high seed output, resistance to herbicides, and an affinity for colonizing disturbed areas (Darbyshire et al., 1999; Metro Vancouver, 2020b; van Mierlo & van Groenendael, 1991). To effectively eradicate wild chervil infestations, control treatments must be repeated and used in combination with complimentary treatment methods, include monitoring plans and follow-up action as needed to prevent recolonization, and effective restoration/revegetation plans to re-establish competitive native communities (Miller, 2016; Miller & D'Auria, 2011).

Biocontrol

Currently no biocontrol agents are available for wild chervil in Canada, although there is some promising research in Europe (Darbyshire et al., 1999; Invasive Species Council of BC, 2019; Metro Vancouver, 2020b).

Chemical Control

Wild chervil is resistant to many types of herbicides with a high potential to impact non-target plants (Darbyshire et al., 1999; Metro Vancouver, 2020b). Trials in the Fraser Valley have shown the best control efficacy using aminopyralid + metsulfuron-methyl, aminopyralid + metsulfuron-methyl + 2,4-D, and diflufenzopyr (Drinkwater, 2015). Other herbicides that have proven control include glyphosate and dicamba (DiTomaso & Kyser, 2013; Magnússon, 2011; Metro Vancouver, 2020b). Higher levels of efficacy are associated with tillage following herbicide application, and fall applications are considered the least effective (King County, 2018; Miller & D'Auria, 2011).

Mechanical Control

All mechanical control treatments should be timed to ensure that early removal doesn't result in new flower stems and sexual reproduction, and late removal doesn't result in vegetative reproduction (van Mierlo & van Groenendael, 1991). Pulling and digging is considered effective for smaller plants and small infestations, but requires careful removal of the deep taproot to prevent regrowth (King County, 2018; Metro Vancouver, 2020b; Province of British Columbia, 2002). This treatment can result in significant soil disturbance, and is ineffective on mature plants with extensive root systems (Province of British Columbia, 2016). Tilling destroys taproots and brings them to the soil surface to dry, and is considered an effective treatment, with control enhanced by pre-treatment mowing/cutting, and removal of cuttings after tilling treatment (Miller & D'Auria, 2011; Shantz, 2018). This is a non-selective treatment that is only appropriate and applicable on flat sites with adequate access for large machinery, and results in significant soil disturbance (Metro Vancouver, 2020b). Mowing reduces seed production and depletes root reserves over time, but is associated with enhanced vegetative growth and even increases in infestation size (Darbyshire et al., 1999; Hansson & Persson, 1994). To be effective, mowing must occur prior to seed set (mid-June in Metro Vancouver) and be repeated diligently for many years to exhaust root reserves (Grime et al., 1988; Metro Vancouver, 2020b; Province of British Columbia, 2016; van Mierlo & van Groenendael, 1991). This treatment method is also non-selective and may damage native plant communities interspersed within wild chervil infestations. Seed head clipping can suppress wild chervil spread by preventing flowering and seed set, but will not reduce infestation size (King County, 2018; Metro Vancouver, 2020b; van Mierlo & van Groenendael, 1991). Flowers should be clipped when the stem is close to maximum growth to ensure that growth of additional inflorescence is not stimulated (Darbyshire et al., 1999; Metro Vancouver, 2020b).

Cultural Control

Burning is not considered effective due to wild chervil's extensive root system (Darbyshire et al., 1999; Metro Vancouver, 2020b). Smothering using cover material to prevent photosynthesis and growth has been used previously with high levels of efficacy, however this control approach is long-term (5 years recommended), is non-selective and requires considerable and expensive restoration efforts (Metro Vancouver, 2020b; Province of British Columbia, 2016). There is also the potential for chemical leaching into soils or watercourses from smothering materials (Metro Vancouver, 2020b).

Control Comparisons

Combining treatments with effective restoration has the highest levels of control; with herbicide application preceded by mowing, followed by tillage and grass seeding resulting in up to 98% control 2 months after treatment in the Pacific Northwest; a six-fold increase in control compared to herbicide treatment alone (Miller & D'Auria, 2011).

Metro Vancouver's Best Management Practices for wild chervil (Metro Vancouver, 2020b), recommends pulling or digging and tilling as manual/mechanical control, recommends chemical control, and partially recommends smothering, but does not recommend burning or grazing. However, that guidance was compiled without an extensive review of targeted grazing literature and updating Best Management Practices with information from this feasibility assessment may be a future consideration.

Wild Chervil Summary

Based on costs and efficacy of treatment (Table 10), it appears that targeted grazing may be cost effective compared to mechanical and chemical treatments. Chemical, mechanical, or grazing treatments all have limitations on efficacy. Hand pulling appears to be the most easily applicable treatment with good efficacy and moderate costs. An integrated weed management approach is recommended, comprised of annually pulling/digging followed by grazing and/or mowing applied with as much frequency as opportunistically possible within each growing season over 2 years, with ongoing monitoring and consistent follow up treatments as necessary. Consideration must be given to the infrastructure and logistical requirements (outlined in Table 15) needed to support targeted grazing treatments, the costs to support those components are not reflected above as they are highly variable and site-specific.

Table 10. Summary of control methods for wild chervil, template adapted from (Bennett, 2006)[a]. Costs are estimated using best available data from literature and practitioner interviews.

Treatment	Summary	Efficacy	Estimated Cost per m² per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m²	Considerations
Targeted Grazing	Pasture or pen livestock in treatment area	Higher efficacy associated with: • treatment repeated within seasons and years • treatment applied when plants are small • treatment applied during spring	\$0.15-\$2	1-4	2-10	\$0.30-\$80	• Allows for control of sites with difficult terrain or environmental sensitivities • May result in additional bare soil or erosion issues • Low nutritional quality, must ensure feed variety
Chemical	Broadcast or spot spraying	• Efficacy is dependent on weather conditions and timing of application • Higher efficacy if sprayed early in the growing season	\$4.62	1	2-10	\$9.24-\$42.60	• Resistant to many herbicides • High potential for non-target plant impacts • Not acceptable near watercourses or in riparian areas
Mechanical Mowing	Area is mowed or cut multiple times per year for several years	Effective when frequency and duration are sufficient to exhaust root reserves. May take decades	\$0.25-\$1	2-4	2-10	\$1-\$40	• Requires flat ground and access for machinery • Labour intensive • Rapid regrowth occurs • Non-selective and damages non-target plants
Mechanical Hand Pulling	Plants are pulled up by hand	Entire taproot removed, treatment occurs prior to seed set, and germinants are removed	\$0.30-\$12	1	2-10	\$0.60-\$120	• Labour intensive • Results in soil disturbance
Mechanical Tilling	Area is tilled to destroy roots	Must address vegetative re-sprouting Efficacy enhanced by pre-treatment mowing/cutting,	\$7.76	1	2-10	\$15.52-\$77.60	• Requires flat ground and access for machinery

Treatment	Summary	Efficacy	Estimated Cost per m^2 per Application[b]	Estimated Applications per Year	Estimated Years of Treatments	Total Estimated Control Costs per m^2	Considerations
		and removal of cuttings after tilling treatment					• Results in significant soil disturbance • Non-selective and damages non-target plants
Mechanical Seed Head	Clipping seed heads to prevent seed release	Reduces sexual reproduction and potential spread, does not provide effective control	$0.30-$12	1	2-10	$0.60-$120	• Does not control of infestations
Cultural Smothering	Smothering materials are placed over infestations	Highly effective if applied for 5+ years	N/A	N/A	N/A	N/A	• Requires considerable time for treatment to work • Non-selective • Requires restoration efforts
Cultural Fire	Infestation is burned	Not proven effective due to extensive tap roots	N/A	N/A	N/A	N/A	• Safety concerns and lack of efficacy

a Referenced against Best Management Practices for Wild Chervil in the Metro Vancouver Region (Metro Vancouver, 2020b).
b Control option costs extrapolated and estimated based on information from Shantz (2018), practitioner interviews, Salmon (2020), and data provided by Metro Vancouver. Grazing costs calculated using practitioner quotes of $150-$2,000 per day, where 1 day of grazing with a herd of 100 goats will remove 1,000m^2 of plant material.

Unintended Spread of Weeds

Digestive Efficiency

Animals have the potential to spread weed seeds by depositing them with waste following consumption and digestion, which represents a valid concern when utilizing livestock to graze invasive species (Bailey et al., 2019; Frost et al., 2012a; Lacey et al., 1992). If animals consume viable seeds there is the potential for seed deposition, enabling the spread of invasive species; however, exposing viable seeds to the digestive tracts of livestock will reduce seed viability, sometimes to a large extent (Bailey et al., 2019; Frost et al., 2012b; Harrington et al., 2011; Lacey et al., 1992). Although there is little literature exploring seed survival of the specific seven target species of this document through livestock digestive tracts, we do know that the viability of weedy species seeds is reduced after passing through the digestive system of domestic livestock. Lacey et al. (1992) found that leafy spurge seed germinability was reduced by 70% by sheep and 56% by goats by testing viability following digestion, and the more complex and efficient digestive systems of ruminant livestock are likely to have higher rates of digestive efficiency (Frost & Launchbaugh, 2003; Ingham, 2008; Lacey et al., 1992).

A study reviewing digestive efficiency for one of the target species, Scotch broom, was found within the literature. Scotch broom seeds ingested by goats had an 8% viability rate following digestion, representing a potential for seed dispersal (Holst et al., 2004). Other work has shown that soft coated seed have their viability reduced to 0% following ruminant digestion, while hard coated seeds retained higher rates of viability (Lowry, 1996). This indicates that seeds with soft seed coats, such as Himalayan balsam and giant hogweed, are less likely to be viable following digestion than hard coated seeds, such as ivy and Scotch broom. To mitigate the potential for seed dispersal, animals should be penned for between 3-4 days prior to moving on to other pastures or sites (Bailey et al., 2019; Frost & Launchbaugh, 2003; Lacey et al., 1992). Guidelines are not specific, although studies have shown that undesirable seeds are passed from livestock digestive systems within that time period, with the exception of seeds from the halogeton plant which requires a 9 day period, and is not a target species (Lacey et al., 1992; Lehrer & Tisdale, 1956; Olson & Wallander, 2002; Wallander et al., 1995)

Livestock Suitability Summary

Grazing livestock are generally separated into three main groups based on their functional feeding habits, these include grazers, browsers, and intermediate feeders (Holechek et al., 2011).

Grazers, such as cattle, have grass dominated diets and although they will eat forbs and shrubs, they generally select for grasses, and often avoid shrubs as they lack digestive mechanisms to address toxicity issues that can often be associated with shrubs (Holechek et al., 2011).

Browsers, including domestic goats, select primarily for forbs and shrubs (Holechek et al., 2011). Small ruminant browsers, like goats, can consume large amounts of forage with volatile oils because they have small mouthparts that allow them to select for the portions of plants with lower levels of oils (Hanley, 1982). Additionally, small sized browsers chew forage to a greater extent than larger ruminants, resulting in a reduction in levels of plant toxicity (Robbins et al., 1991; White et al., 1982). Goats also have a large liver relative to their body mass, which allows for them to effectively process secondary compounds and mitigate toxicity effects.

Intermediate feeders, such as domestic sheep, will utilize grasses, forbs, and shrubs equally, with the ability to adapt feeding habits to the available forage resources (Holechek et al., 2011). Sheep are at higher risk for injury, they have issues with becoming stuck on their backs and subsequently vulnerable to predation, are prone to choke or bloat on rich feed, can get stuck in blackberry patches unless recently shorn, and in wetter environments wet wool creates environments conducive to fly and maggot development.

Pigs can be effective, but represent significant challenges relative to public relations and issues relating to manure odours (King County, 2014). Additionally, there is a risk associated with feral pigs if escape occurs.

Table 11. Livestock suitability summary.

Livestock Type	Advantages	Disadvantages
Cattle	• Capacity to ingest large amounts of forage	• Select for grasses, avoid shrubs and forbs (invasive plants) • More susceptible to toxicity
Sheep	• Adapt feeding habits to available plants	• Consume less shrubs and forbs than goats • More susceptible to toxicity • More susceptible to bloat and choke from changes in feed • Higher risk for injury and predation
Goats	• Select for browse and shrubs (invasive plants) • Larger range of palatable plants than other livestock • Less susceptible to toxicity issues • Reduced risk of seed spread due to greater levels of chewing and higher digestive efficiency	• Curious and must be monitored closely • May girdle off-target trees
Pigs	• Highly adaptable and will feed on any available forage • Will root out plant roots and crowns	• Difficult to contain, likely to escape and become feral • Considerable issues with odours and public relations

It is important to match the livestock species with the target plant by taking into consideration grazing preferences, toxicity, and palatability (Olson & Launchbaugh, 2006). For Metro Vancouver, goats are suggested as the most suitable livestock to perform targeted grazing based on efficacy, ease of handling, public perception, and availability of herds.

Practitioner Interview Summary

Fourteen practitioners were contacted and interviewed as part of this project. There is a general shortage of targeted grazing practitioners in Western Canada; limiting the number of interviews. Most practitioners interviewed service Vancouver Island, the East Kootenays, Thompson/Okanagan, Northern British Columbia, Southern Alberta, and one had experience in the Fraser Valley. Five practitioners expressed interest and willingness to work in the Metro Vancouver Region: Creekside Goat Company, Vahana Nature Rehabilitation, The Canny Crofter, Natasha Murphy, and SXDC Ltd.

Goats are the primary livestock species used by targeted grazing practitioners, they are noted as more agile and hardy relative to other types of livestock, with greater affinity for consuming invasive plants and higher efficacy in reducing infestations. 'Kiko' goats were noted as better able to handle wet/rainy conditions than other breeds. This aligns with information from the literature review. Herd sizes ranged from 5-1,500 head, with flexibility around the number of goats that could be deployed to specific treatment areas. Kidding on site was not recommended for any project areas that have the potential for public interface as there is naturally occurring mortality associated with kidding that could result in negative public relations. Most practitioners run mixed age herds, but dry does (females) and wethers (neutered males) are suggested as the best suited livestock kind as their nutritional requirements are not as critical from a producer perspective (they are not pregnant or nursing) and they do not have the odours associated with Billy goats. It was also noted that local animals will have a palate for local plants. All practitioners were diligent in maintaining herd health and vaccination/deworming schedules.

Herd rental rates vary widely and are very site/job specific. Quoted prices ranged from a minimum of $150/day to $2,000/day, dependent on herd size and whether the rental cost was inclusive of transportation costs, and other costs. Targeted grazing treatments within the city of Calgary cost $2,000 per day, and included transportation, water, fencing, and a self-contained camper. See Appendix 3: Practitioner Interviews for more detailed information on cost ranges.

Transportation costs were often built into herd rental rates, but in some cases were added to the bid cost separately or billed. All herds require at least one staff member on site at all times to monitor livestock and address any issues. This requires a night pen/home base area that can support on-site accommodation (camper/trailer) and can tolerate temporary, high intensity use – often described as a 'sacrifice' area. Moving night penning locations during the treatment will help address degradation issues and aid in spreading nutrient deposition (urine and feces) across the treatment area, which may increase revegetation success. Fencing in the form of panels or electric net fencing are necessary infrastructure, good access roads and the ability to do site prep, such as removing poisonous plants and ensuring water access, is important. Most practitioners utilize herding dogs, livestock guardian dogs, and firearms for predator defence. Liability insurance is carried by most practitioners, generally between $1-5 million, some proactively carrying insurance for each livestock guardian dog in case there are conflict issues.

Practitioners noted that goats are relatively easy to train to consume new target species, with training taking a relatively short time (approximately 3 days) for goats to begin selecting target plants. Providing a variety of forage is critical to reduce potential toxic effects of some target plant. Five practitioners had experience with the priority weed species identified for Metro Vancouver, and observations around timing of grazing, frequency of grazing, and efficacy aligned with what was outlined in the literature review component of this report. The anecdotal feedback regarding the efficacy of targeting browsing noted that efficacy is based on reliable herd management, and monitoring and flexibility to make changes on site as necessary. Practitioner interviews noted that maintaining livestock on site for 48 hours following treatment will ensure that any potential seeds carried by animals are expelled before moving off site, therefore reducing the potential to spread invasive species. This aligns with recommendations from Frost & Launchbaugh (2003), who also note that animals should be penned for 3-4 full days following targeted grazing treatments to mitigate potential seed dispersal offsite.

Public relations are an important consideration of any urban targeted grazing project, it is key that the public be educated that grazing is a tool/process that can be effective under certain conditions and that members of the public have a positive experience.

There are several sources of potential conflict:

- off-leash dogs represent a threat to livestock
- no-touch policies mitigate distraction of goats by members of the public and potential disease transfer
- no feeding policies address potential poisoning from garden trimmings etc. (Rhododendron, azaleas, western yew are all poisonous)
- 24/7 monitoring addresses livestock escape, livestock hung up in trees by feet or horns, livestock theft, and vandalism
- wandering livestock guardian dogs may result in unhappy neighbours if proactive communication does not occur

Goats are curious and require constant supervision. Most practitioners use various forms of social media and websites for public outreach with positive reception. Off-target effects noted by practitioners include grazing/browsing of non-target plants, including girdling of trees in some cases. It is important to discuss which trees are expendable and which should be protected by burlap or wire during the duration of grazing pressure. Clear communication by land managers regarding priority plants in the target area should occur prior to the grazing treatment. Erosion can be an issue on steep slopes. The process of 'trailing', which leads to the creation of paths in target areas is largely unavoidable.

Some key considerations for Metro Vancouver to facilitate viable practitioner involvement are proactive bylaw amendments, a municipal employee to act as liaison to handle public access/education etc. Longer-term seasonal contracts will support local industry, mitigate transportation/staff costs, and support livestock health.

Legal Requirements and Considerations

Certain legal requirements must be considered and fulfilled to enable targeted grazing in Metro Vancouver. Aldergrove Regional Park was used as an example site while investigating several of these considerations.

Regulations

Specifically for Metro Vancouver Regional Parks, animals are addressed in Part 8 of 'Consolidation of Greater Vancouver Regional District Regional Parks Regulation Bylaw No. 1177', which notes that:

8.2 No owner shall cause, permit, or allow an animal to:

(a) dig up, damage, deface, destroy, or otherwise injure any natural park feature or regional park property;
(b) disrupt, disturb, frighten, or intimidate a person or other animal, including by licking, jumping, snarling, growling, or pursuing the person or animal; or
(c) travel anywhere that may cause damage to, or otherwise injure, a natural park feature or regional park property.

This bylaw may or may not provide a barrier to allowing livestock to perform targeted grazing in municipal parks as by definition livestock will be damaging park features. Animal control bylaws vary by municipality and may represent barriers to targeted grazing within each specific municipality. Within the Township of Langley and City of Abbotsford bylaws do not seem to prevent targeted grazing within the municipalities (City of Abbotsford, 2020b; Animal Control Bylaw 2005 No. 4440, 2005).

Permits, Licences, and Insurance

Business licences are required to conduct business within different municipalities, which can represent a barrier if practitioners are working across multiple municipalities. For example, Aldergrove Regional Park could be as a prime candidate for targeted grazing, however it overlaps two separate municipalities, the Township of Langley and the City of Abbotsford, both of which require business licences for any business undertaken within the municipalities (City of Abbotsford, 2006; Township of

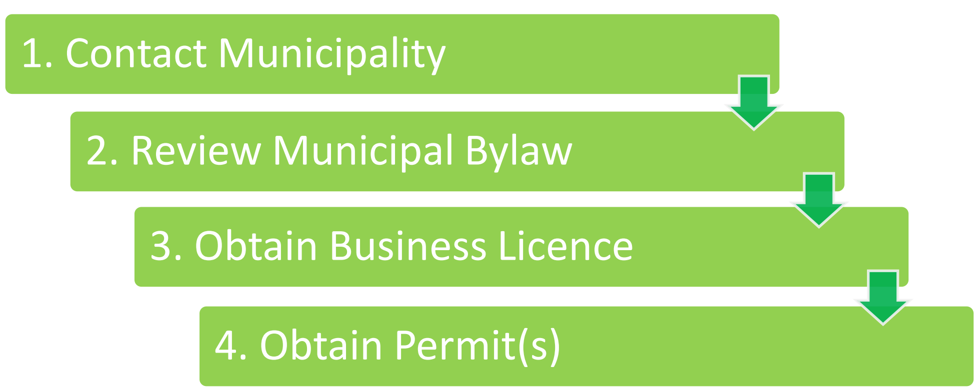
Langley, 2020a). As of April 2020, an Inter-Municipal Business Licence was made available for participating communities in the Fraser Valley, including the City of Abbotsford and Township of Langley, as well as Chilliwack, Delta, Hope, Kent, Merritt, Maple Ridge, Mission, Pitt Meadows, Surrey, and Harrison Hot Springs (Township of Langley, 2020b). Although this is beneficial for the eastern portion of Metro Vancouver, it does not cover a large component of municipalities located in the western portion. Some municipalities in that region also have inter-municipal business licences that cover select components of the Metro Vancouver Region [eg. Inter-Municipal Business Licence for Port Moody, Coquitlam, and Port Coquitlam (City of Port Coquitlam, 2020)], but Metro Vancouver covers 21 different municipalities, one Electoral Area, and one Treaty First Nation, and business licensing could represent a barrier both financially and in the form of time constraints, as applications may take up to 30 days to process (City of Port Coquitlam, 2020; Township of Langley, 2020a).

Permitting may be required to enable targeted grazing within Metro Vancouver Regional Parks, but in the City of Abbotsford it appears that permits would not be required for fencing or to enable grazing on the portions of parks located within the Agricultural Land Reserve (City of Abbotsford, 2020a). However, discussion with municipal representatives noted that a building permit would be necessary for any new buildings or structures, which may include temporary fencing. In the Township of Langley a park permit ($50) is required if temporary or permanent structures are erected, or if plants or vegetation are moved (Township of Langley, 2020d). Permit requirements vary by municipality.

Insurance requirements vary between municipalities and the nature of activities undertaken, municipal staff will provide information on insurance process and requirements at the time of application (Township of Langley, 2020c).

Legal Requirements Process

Prior to initiating any targeted grazing projects, or engaging in any substantive planning on targeted grazing projects, the parties should ensure that they complete the following process to verify that municipal bylaws and permitting enable targeted grazing:



Partnerships

The importance of effective partnerships can't be overstated in deploying successful targeted grazing treatments, especially in urban municipalities (Frost et al., 2012).

Public Communications

To position projects for success communications efforts should occur before, during, and after grazing treatments. The public is generally excited and happy to see goats and are keen to interact and observe. It is important that the public has a positive experience with the livestock, but it must be clear that the grazing treatment is not a petting zoo. In some urban areas practitioners have noted up to 300 people stopping by per day to see the goats, and effectively communicating that these are working animals and that there is a 'no-touch' policy is needed to allow for effective targeted grazing and disease control.

Encouraging public support through extension efforts such as education days, school visits, citizen science, public involvement in long-term planning, local school monitoring projects and restoration planting following control efforts are all proactive approaches to engage the community in invasive species management and targeted grazing. Most practitioners leverage social media (Facebook, Instagram, and YouTube) to showcase targeted grazing treatments, which is positively received by the general public. Early engagement with community associations is important to build relationships, serve as a potential volunteer base, provide local knowledge, and solutions to problems.

Municipal Involvement

In cases where a municipality is the employer, they are the most important partner in the grazing treatment. Establishing a good working relationship with clear roles and responsibilities (i.e. who is responsible for communication? For contacting other partners?) is critical to success. Practitioners have noted that it is preferred if municipal employees are able to act as the primary liaison to handle public access and education to allow practitioners to focus on livestock management and contract fulfillment.

Police and Bylaw

Proactive bylaw amendments are an excellent approach to enabling successful targeted grazing treatments in a municipality. Amendments to allow livestock in urban areas, parking RVs on roadsides/in residential areas, the ability to procure one license or an inter-community license enabling practitioners to work in multiple municipalities and reduce administrative burden are examples of proactive bylaw amendments discussed by practitioners during interviews. Establishing good relationships with police and bylaw effectively allows practitioners to address issues associated with off-leash dogs and vandalism by reaching out to bylaw and police contacts. Off-leash dogs represent a large risk to livestock and livestock guardian dogs, effective education in conjunction with bylaw and/or police enforcement and ticketing are necessary to mitigate this risk. Vandalism is an unfortunate reality, and police or bylaw drive-bys, especially at night, are effective in preventing vandalism to the targeted grazing operation.

Procuring Targeted Grazing Services

Secure funding is one of the most important components to enabling successful grazing treatments. Multi-year approaches with dedicated funds will result in the best control as practitioners can focus on the project, learn site-specific characteristics, and adapt the grazing prescription to increase efficacy. Yearly retainers paid monthly for a specified number of grazing days per season allows flexibility for practitioner to graze at the most effective time of year, provides more financial stability and the ability to expand grazing capacity, resulting in better treatment efficacy over the long-term.

Logistics

Animal Husbandry Considerations

To ensure effective grazing treatments, a priority should be placed on providing secure spaces for grazing and resting (Chow, 2018). It is important to note that livestock take time to adjust to new areas and sounds, and are more effective in repeat treatments where they have familiarity with terrain, target plants, traffic/noises, etc.

Shelter

Livestock require shelter from cold and/or heat, and to provide a secure bedding area. Goats in particular dislike wet conditions and are at a higher risk for chill stress than other types of livestock and dry shelter areas should be provided to reduce livestock stress (Meat & Livestock Australia, 2007). Night penning often takes advantage of canopy cover from trees to provide shelter as animals rest, and can provide shelter from both rain and heat if the tree canopy is dense enough. Some practitioners advertise their animals as ‘range ready’ which indicates that their animals have less shelter requirements and can utilize small portable calf shelters to fulfill shelter requirements.

Fencing

Fencing is necessary for passive management approaches to contain livestock to the treatment area and focus grazing on target species. Fencing should be appropriate to contain the livestock species being used for the grazing treatment, and maintained clear of obstacles that can help animals go over or under fences (Meat & Livestock Australia, 2007). Goats in particular are curious animals and will try to find ways out of enclosures, necessitating constant monitoring, and in cases where goats escape the fence should be repaired as soon as possible to ensure that escape habits are not reinforced (Meat & Livestock Australia, 2007). Night penning requires portable fencing panels, and night pens are moved often to keep animals comfortable. Electric net fencing is used as needed to secure the grazing area. Issues with public damage to fencing have occurred and should be considered. 24/7 on-site herd management helps reduce fence related issues and placing the practitioner's phone number on site and along fencing for emergencies (such as escapees) is recommended.

There is the opportunity to utilize active herding management to reduce the need for fencing. This approach utilizes limited fencing in strategic locations and actively manages goat presence and grazing intensity through herding. Active herding has a different visual representation than passive herding, which may be more desirable for a park setting.

Additional Forage Resources

To reduce potential livestock health issues, a mixture of forages should be available for livestock use. This is particularly important when plants with known toxicity issues, such as ivy or Scotch broom, are the target plants. Additional forage resources can include non-target plants in the treatment area (dependent on whether or not the consumption of significant amounts of non-target plants is acceptable) or supplemental forage resources such as hay, which require a designated feeding area to reduce off target impacts. Providing a variety of forages will allow livestock to manage their own toxicity levels as they adjust to consuming target plants with toxic compounds.

Poisonous Plants

Practitioners will need permission and time to remove poisonous plants prior to livestock entry to ensure that no accidental livestock fatalities occur during grazing treatments.

Water

Water requirements are site specific and depend on the water resources and infrastructure available on site. If water is available on-site livestock can either be provided access to those water resources, or water can be pumped into a stock tank. If water is not available on-site, then water hauling will be undertaken by either the practitioner or the organization hiring the practitioner. Often water is a component or consideration in the bidding process. Livestock require clean water with good accessibility, generally hardened banks are preferred relative to muddy banks both from a livestock health perspective and an environmental quality perspective.

If hauling is necessary practitioners appreciate if it is done by the employer so herders can stay in camp and monitor livestock/grazing. 275-gallon tanks are commonly used as they fit in the back of pickup trucks or on flatbed trailers and can be filled relatively quickly, many practitioners own and utilize these types of tanks. Livestock water requirements vary dependent on temperatures and moisture content of forage, however goats will require 1 gallon of water per day in hot conditions and it is good to plan around those requirements (Salmon, 2020).

Livestock Guardian Dogs

Livestock guardian dogs were used by every practitioner interviewed and are an integral component of targeted grazing operations. Livestock guardian dogs can result in conflict with the public and other dogs. Beware of dog signs and effective communications efforts can assist in reducing conflict issues, many members of the general public are not familiar with working dogs and education is usually a requirement.

Site Assessment and Suitability Criteria

Determination of site suitability requires review of three key aspects:

1. Environmental Suitability
2. Access Suitability
3. Available Infrastructure

Environmental Suitability

The target area must be environmentally suited for grazing treatments; riparian areas are not likely suitable as livestock may cause off target environmental degradation. An area with shade or cover is necessary to use for night pens, and is often considered a ‘sacrifice zone’ as off target degradation will occur, although deposition of animal wastes tends to act as a fertilizer and these sites often recover quite quickly. There needs to be clear communication of which native or rare plants must be retained in grazing treatment areas, and discussions on impact levels to off target plants are important. Often for targeted grazing treatments to be effective there will be off target effects, which may have an unpleasant visual outcome despite a lack of long-term damage to those plants.

Access Suitability

There must be suitable access to enable trucks and trailers access to the grazing treatment area. Additionally, there must be adequate access along proposed fence lines to enable the construction of fencing, access to additional forage resources, and access to water resources. It is ideal to transport livestock directly to the fenced treatment area rather than unload and herd to the treatment area across terrain that is unfamiliar to the livestock and contains uncontrollable unknowns.

There should be 24/7 access for practitioners in and out of the site, and access to an adequate area to create a home base for the practitioner and livestock. Practitioners can set up camp in one area and trail livestock into the target area if access to target areas does not support vehicles, but this is not the desired choice as it represents logistical issues around livestock management and security. If applicable, there should also be trails available for livestock to access separate patches of invasive plants, and/or cut into dense infestations to allow for ease of access. Additional considerations should be given to public access to the grazing treatment. If public engagement to encourage project support is an additional objective, then access for public viewing should be an additional consideration. To adequately evaluate access suitability and fully consider targeted grazing access considerations, a site visit is required.

Available Infrastructure

A basecamp area is necessary for the practitioner and the livestock, the livestock require shelter (constructed or under dense tree canopy) for resting, and it must be in an area that accommodates the practitioner's camping equipment. Areas such as public theatres or other existing buildings/structures can provide good shelter and a basecamp area. Chain link fences are excellent for containing livestock if they exist on the site and can be complimented by fence panels and electric fencing. Existing water infrastructure, such as taps that can be used to fill troughs or natural water features, are beneficial.

Pre-Grazing Data Requirements

To set the practitioner up for success a file review of the area should be undertaken, with pertinent data summarized and communicated. Maps should be provided that include important data considerations such as infestation type and area, water points, infrastructure (fences, shelters, etc.), trails, roads, and proposed basecamp areas.

Data requirements include:

- the identification of target areas, target species, infestation area (acres or hectares) and infestation characteristics (eg. density and distribution)
- environmental suitability information, such as information on terrain (topographic maps) and sensitive areas that should be omitted from grazing treatment
- access suitability information, maps with roads, water resources, etc.
- information on available infrastructure, existing fences, and their condition

Pre-grazing site visits are crucial and should be performed in advance by the practitioner to inform development of the grazing plan.

Potential Carbon Implications of Treatment Options

This section will assess the potential carbon implications of targeted grazing treatments relative to chemical and mechanical treatment options for Himalayan blackberry infestations at the Aldergrove Regional Park. This assessment takes into consideration the full suite of inputs relative to each control method and is specific for the case study area.

The total area of Himalayan blackberry in Aldergrove Regional Park was assessed at 4.7 ha via geospatial analysis:

Table 12. Himalayan blackberry infestations in Aldergrove Regional Park.

Polygon ID	Species	Area (m^2)	Area (ha)
1608	Blackberry	3,200	0.32
1208	Blackberry	1,200	0.12
344	Blackberry	350	0.035
2075	Blackberry	1,500	0.15
1926	Blackberry	1,700	0.17
3004	Blackberry	5,800	0.58
4194	Blackberry	4,600	0.46
2310	Blackberry	1,800	0.18
2735	Blackberry	3,000	0.3
728	Blackberry	1,200	0.12
5708	Blackberry	6,800	0.68
3271	Blackberry	4,000	0.4
1511	Blackberry	1,750	0.175
1511	Blackberry	1,750	0.175
3386	Blackberry	3,000	0.3
3843	Blackberry	5,000	0.5
TOTAL		**46,650m^2**	**4.7ha**

Figure 1. Blackberry infestation locations in Aldergrove Regional Park (map provided by Metro Vancouver Regional Parks).

Table 13. Potential carbon dioxide emission comparisons for each control method for Himalayan blackberry in Aldergrove Regional Park.

Control Method	Emission source	Parameters	Estimated kg CO_2 Emissions (treatment of 4.7 ha)
Targeted Grazing	Transportation	• Average distance travelled by available practitioners = 1,425kms • Emission rate of loaded gooseneck trailer of 0.55kg CO_2/km (Kannan et al., 2016)	784
	Manure	• No additional GHG emissions. Manure occurs regardless of location	0
	Generator	• Power provided on site	0
	Water hauling	• Water provided on site	0
		Estimated Total Emissions	**784**
Other Methods for Comparison[a]			
Chemical	Herbicide use	• 48.6kg CO_2/ha (Audsley et al., 2009)	228
	Transportation	• Estimated travel of 50kms total (to and from site)[b]	14
		Estimated Total Emissions	**242**
Mechanical	Mower Equipment	• 22kg CO_2/ha (Gu et al., 2015)	103
	Transportation	• Estimated travel of 50kms total (to and from site) and 1 truck**	14
	Disposal	• Landfill Disposal: ○ Estimated travel of 50kms total (to and from site) and 2 trucks** • Burning on Site: ○ 1,770g CO_2/kg (Burling et al., 2010) using 500 kg biomass • Composting: ○ 43-563kg CO_2/tonne wet waste (Boldrin et al., 2009) using 500 kg biomass	Landfill = 28 Burning = 885 Composting = 22 - 282
		Estimated Total Emissions	**Landfill = 145** **Burning = 1,002**

Control Method	Emission source	Parameters	Estimated kg CO_2 Emissions (treatment of 4.7 ha)
			Composting = 139 - 399
Manual	Transportation	• Estimated travel of 50kms total (to and from site)[b] and 10 vehicles used	140
	Disposal	• Landfill Disposal: ○ Estimated travel of 50kms total (to and from site) and 2 trucks** • Burning on Site: ○ 1,770g CO_2/kg biomass burned (Burling et al., 2010) using 500 kg biomass • Composting: ○ 43-563kg CO_2/tonne wet waste (Boldrin et al., 2009) using 500 kg biomass	Landfill = 28 Burning = 885 Composting = 22 - 282
		Estimated Total Emissions	**Landfill = 168** **Burning = 1,025** **Composting =162 - 422**

a Note that these comparisons did not take into consideration the carbon emissions of manufacturing machinery.
b Assuming 0.28 kg CO_2/km median emissions rate for light pickup truck (Natural Resources Canada, 2020)

Emissions Legend

Highest emissions (>1,000 kg CO_2)
Higher emissions (500-1,000 kg CO_2)
Lower emissions (100-499 kg CO_2)

Carbon dioxide emissions associated with targeted grazing at Aldergrove Regional Park would be lower than burning, but higher than emissions from mowing and manual control, which include some emissions from disposal of invasive plant material at a landfill or industrial composting facility. Emissions from grazing would be considerably lower if a local herd was available, although this estimate assumes manure would be managed offsite and not transported to a disposal facility.

Studies have noted that substituting grazing for conventional lawnscaping practices (mowing and compost application) reduces greenhouse gas emissions by 34-37% even when methane and nitrous oxide emissions from grazing animals are considered (Lenaghan, 2016), although the transportation emissions from B.C.'s available practitioners are substantial when compared to other control methods which can be locally sourced.

Biosecurity and Disease Consideration

Biosecurity and disease considerations were assessed only for goats as they are the suggested and currently available livestock type to practice targeted grazing in Metro Vancouver.

Disease Risks

Diseases that goats are at risk for carrying include:

FEET	Footrot (*Dichelobacter nodosus*)								
URINE	*Leptospira spp.*	Border Disease virus BDV							
EYES	Pink eye (*Mycoplasma conjunctivae, Chalmydophila pecorum*)	Malignant Catarrhal Fever MCF							
RESPIRATORY TRACT	Respiratory viruses	Caseous lymphadenitis	Maedi Visna virus MV	Ovine Pulmonary adenomatosis	Enzootic nasal carcinoma				
SALIVA	MV/Caprine Arthritis Encephalitis CAE	Johnes	Rabies	MCF	Foot and Mouth Disease	BDV			
REPRODUCTIVE TRACT	*Chlamydophila abortus*	*Toxoplasma gondii*	*Coxiella burnetii*	*Listeria Monocytogenes*	*Brucella ovis and B. melitensis*	Scrapie			
SKIN	Contagious ecthyma	Caseous lymphadenitis	Mange Chorioptic and Psoroptic	Lice sucking and biting	Sheep keds	Ringworm			
FECES	Parasites intestinal and lung	Parasites with wormer resistance	*Salmonella spp.*	*Listeria monocytogenes*	*Campylobacter fetus fetus and C. jejuni*	*Coxiella burnetii*	Johnes Disease		
UDDER (MILK)	*Listeria monocytogenes*	Caseous lymphadenitis	*Brucella melitensis*	*Staphlococcus aureus*	*Toxoplasma gondii*	Coliform bacteria	Johnes Disease	MV/ CAE	*Caxiella burnetii*

Figure 2. Goat diseases displayed by main area affected, from (Balke & de With, 2013).

Some of these diseases can be prevented through vaccination, while others must be treated with antibiotics or other therapeutic approaches, or in some cases require culling. Some zoonotic diseases can transfer from goats to humans. ORF (sore mouth infection) is considered the most common zoonotic disease risk presented by goats, it is found primarily in goats and sheep, presenting as sores around the mouth/lips, and can be transferred to other animals or humans through direct contact (CDC, 2020). Other zoonotic diseases exist, but transmission is more complex and unlikely to the general public. To prevent infection of zoonotic diseases in people a ‘no-touch’ policy should be instituted.

There are a few diseases that can transfer between goats and cattle that are important to consider when grazing in Metro Vancouver with its high value dairy sector. These include Bovine Viral Diarrhea, Bluetongue, Johnes, and Malignant Catarrhal Fever (MCF) (Balke & de With, 2013). Bovine Viral Diarrhea is an economically important disease of concern to dairy farmers that causes respiratory and reproductive issues in cattle, and can be passed between goats and cattle (Balke & de With, 2013; The Cattle Site, 2020). Persistently infected animals represent a reservoir, and risk of spread can be effectively reduced by separating goats from other cloven hoofed animals, and ensuring that proper biosecurity measures are taken when travelling from farm to farm (cleaning/changing equipment, boots, clothes), and by ensuring that cattle are vaccinated against Bovine Viral Diarrhea (Farm Health Online, 2020; The Cattle Site, 2020). Johnes is a bacterial infection that is spread through contaminated fecal matter, and can survive as long as one year in pastures, requiring 100 hours of sunlight to kill off the bacteria (Balke & de With, 2013; Province of Manitoba, 2020). To mitigate spread, animals should be tested for Johnes prior to targeted grazing contracts, some practitioners interviewed noted that they do blood work for Johnes to ensure herd health, with the intent of culling any animals that test positive to remove them from the herd. Malignant Catarrhal Fever (MCF) is a very rare virus with no vaccine that is spread from nasal discharge and placenta that is fatal to many other ruminants including deer, moose, bison and cattle (Balke & de With, 2013; Province of Manitoba, 2020). MCF does not last long in the environment, and not all susceptible species will present the clinical disease if infected (Balke & de With, 2013). The best prevention is ensuring that goats are separated from other susceptible ruminants (Balke & de With, 2013). Bluetongue is an insect-borne virus, spread specifically by midges, and risk can be reduced by insect control or moving animals into shelter in the evenings (Balke & de With, 2013). Bluetongue has not been reported in goats in BC since 1987 (Balke & de With, 2013).

In broad strokes, disease transfer risk can be reduced by taking proper biosecurity measures, such as preventing contact via fencing, only using vaccinated and healthy herds, and ensuring that cattle do not overlap goat grazed areas. Gastrointestinal parasites cannot be transferred from cattle to goats (Province of Manitoba, 2020; The Beef Site, 2010).

Biosecurity

Biosecurity refers to the measures taken to protect livestock from biological harm, including prevention of disease, containment of disease, and reducing risk of infection and illness (Balke & de With, 2013; Canadian Agri-Food Research Council, 2003; Canadian Food Inspection Agency, 2020).

Suggested biosecurity precautions for off site locations are outlined by the Government of Canada (Canadian Food Inspection Agency, 2020) and include:

1. Maintain herd health through records and vaccination
2. Conduct a risk assessment for each off-site activity, the biosecurity practices in use at the site, and your ability to implement additional biosecurity practices as needed.
3. Attend off-site activities that are suitable based on your risk assessment and/or that have biosecurity programs that are suitable for your goats.
4. Transport your goats in a vehicle that has been cleaned and disinfected prior to use. Ideally, this vehicle is dedicated exclusively to your farm's use.
5. Prevent commingling and direct contact and limit proximity with other goats and livestock in transit and on-site.
6. Supply bedding and feed from your home farm.
7. Ensure a clean supply of water on-site.
8. Bring feeders, water buckets, and grooming and handling equipment from your home farm for exclusive use on your goats.
9. Limit handling of your goats by others, but when it is necessary and require that handlers wash and/or sanitize their hands before and after contact with the animals.
10. Change clothing, sanitize boots and equipment when travelling between farms

All practitioners interviewed that currently ran goats for targeted grazing had their herds fully vaccinated, and a number maintained closed herds to reduce disease transfer potential. Disease transmission mitigation procedures should be discussed in advance of contracts. Practitioners should have the ability to remove sick or injured stock from the site immediately.

Availability of Herds

There is a general shortage of targeted grazing practitioners in Western Canada. However, the industry appears to be gaining momentum and there are several individuals interested in establishing targeted grazing practices, but are hesitant to invest the capital costs without assured work. This represents an opportunity for NGOs, municipalities, and other levels of government to invest in an emerging local business sector by providing assured income stability through longer-term contracts and/or retainers as new businesses are established.

Five practitioners expressed interest and willingness to work in the Metro Vancouver Region:

Table 14. Practitioners interested in working in Metro Vancouver Region.

Practitioner	Information
Creekside Goat Company	Robert Finck 400 head of goats Based in Southern Alberta Significant experience with weed control in municipalities
Vahana Nature Rehabilitation	Cailey Chase 230 head of goats Based out of Kimberly, BC Experience working in large cities (Calgary)
SXDC Ltd.	Clayton Harry 200 head of goats Based in Williams Lake area In start-up, training phase No prior experience
The Canny Crofter	Jayne D'Entremont 60 head of goats, 23 head of sheep Based out of Barriere, BC Experience working on private rural properties
Natasha Murphy	Natasha Murphy 5 goats, intending to build to herd of 50 Based out of Vancouver Island Experience in small scale weed control and ecological restoration on private properties

Final Considerations and Logic Model

Invasive species control is a difficult task that requires long-term integrated approaches to be successful. No one treatment works as a 'silver bullet' for any of the target species reviewed in this report. All treatments have efficacy limitations, with increased efficacy directly correlated with increased commitments to control efforts and increased funding. Success usually requires implementing long-term integrated weed management systems focused on consistency in treatment application, long-term monitoring, regrowth management, and effective restoration efforts (Bailey et al., 2019; Popay & Field, 1996).

Managers are often seeking predictability in results of control efforts and plant community responses. However, the nature of invasive species management, including target grazing, is influenced by many complex factors that make predicting outcomes difficult. Successful targeted grazing prescriptions require significant site-specific environmental data, excellent animal management skills, and an understanding that results are not immediate, an adaptive process is necessary for success, and will most likely require long-term and ongoing treatments (Bailey et al., 2019; Frost et al., 2012). Accepting the learning curve is important.

Plants and plant communities are influenced by and respond to control efforts in varied ways, which may result in increased risk of invasion by new weedy species following targeted control efforts (Radosevich et al., 2007). Target species often have compensatory results to control efforts that can result in reinvasion, and in cases where target species are removed, a gap in the plant community exists that is susceptible to colonization by other invasive species if not addressed (Sheley & Krueger-Mangold, 2003). Restoration and revegetation plans are a critical follow up component of any weed management control effort.

Successful targeted grazing treatments are dependent on several different social, economic, and environmental factors (Frost et al., 2012; McGregor, 1996):

- Commitment and funding of long-term control efforts
- Integration of targeted grazing with other control treatments
- Suitable target areas
- Effective partnerships and communications
- Solid livestock training and handling skills
- On site management of livestock
- Reliable staff and livestock herding/guardian dogs

Other unique considerations include the opportunistic theft of livestock and opening of fences to 'free' livestock. Public scrutiny may be an issue, and there is the potential for well-intentioned animal rights activists to harass practitioners or livestock in criticism of animal management.

A summary of the logistical considerations is provided in Table 15. Identification of roles and responsibilities in the grazing contract, including which party is responsible for funding each logistical component, is necessary to ensure success.

Table 15. Logistics checklist for those considering targeted grazing at sites in Metro Vancouver.

Factor	Logistical Consideration(s)	Action(s)
Legal Requirements	Must ensure grazing use is enabled by municipal bylaw(s), obtain business licence, and necessary permits	1. Contact municipality 2. Review municipal bylaw 3. Obtain business licence(s)[a] 4. Obtain permit(s)[b]
Grazing Contract	Roles and responsibilities	Determining which party is responsible for which logistical component, including funding
Coordinator	Coordination of various moving parts of treatment is needed to ensure success	Ensure a coordinator is available for contract management, communications, and to coordinate with researchers/partners[c]
Partnership(s)	Proactive communication and partnership building ensures success	Engage with: • Police • Bylaw • Community Associations • Adjacent neighbours • BC Society for the Protection of Animals
Communication	Public Education	Encourage support through public engagement efforts such as education days, school visits, citizen science, public involvement in long-term planning, local school monitoring projects and restoration planting
Base Camp	Must have a base camp area for practitioners to stay on site and monitor livestock 24/7	Ensure that potential targeted grazing treatment sites have areas suitable for base camps Power/water/sewer is not necessary for self-contained units, however spaces must be flat and located relatively near to treatment areas (close enough that livestock can be herded from base camp to treatment areas
Animal Husbandry	Shelter	Barns or adequately treed areas must be available to provide a secure bedding area
	Fencing	Portable fencing panels or electric fencing used for night penning and to concentrate use in target areas
	Additional Forage Resources	Allow hay or grazing of non-target plants Ensure hay is weed free to avoid introduction of additional invasive species
	Poisonous Plants	Obtain permission to scout and remove poisonous plants prior to grazing
	Water	Provide access to on-site water or haul water to site
	Livestock Guardian Dogs	Allow guardian dogs off-leash to protect from predation
	Access	Provide suitable access for long vehicles hauling livestock 24/7 access for practitioners Access to power/water/sewer is not necessary for self-contained units but would be beneficial if available Restrict public access to grazing sites
	Livestock Management Dogs	Ensure that off leash working dogs are permitted

Factor	Logistical Consideration(s)	Action(s)
Treatment Efficacy	Review efficacy of all treatment options	Ensure funding will support targeted grazing to meet timing, frequency, and duration needs May require a longer-term service contract and resources to write/oversee that contract
Pre-Grazing Data	Pre-grazing data is necessary to develop the grazing plan	Provide: • Map of target areas, target invasive species, and infestation density • access information • infrastructure information
Site Assessment	Determine site suitability by reviewing criteria	Review site suitability for targeted grazing treatments based on: 1. Environmental Suitability (e.g. riparian areas are not likely suitable as livestock may cause off target environmental degradation) 2. Access Suitability 3. Available Infrastructure
Grazing Plan	A grazing plan is needed to implement the grazing treatment	Develop a grazing plan using the variables outlined in Appendix 4
Field Testing	Test grazing efficacy on invasive species	Implement grazing plan and follow-up monitoring to assess treatment success
Biosecurity	Reduce risk of disease	• Implement a 'no-touch' policy Ensure herds are vaccinated and healthy • Use fencing to reduce contact with other livestock • Preferentially select for closed herds
Weed Spread	Reduce risk of weed spread	Pen livestock for 3-4 days prior to moving off site
Manure Management	Address any manure build up	• Develop onsite manure management protocols • Investigate options for offsite manure disposal (additional cost and CO_2 emissions from transport)
Liability Insurance	Practitioners must carry liability insurance	Ensure as part of the grazing contract, that practitioners carry liability insurance at a rate acceptable to the client
Herd Availability	Limited practitioners	Contact practitioners who have expressed interest
Transportation	No practitioners in the lower mainland	Transportation costs will need to be assigned in the grazing contract. The grazing contract will need to be substantial enough to be economically viable for practitioners if they are to travel large distances
Restoration	Plan for restoration and revegetation plans following weed control	Ensure control does not overwhelm organizational restoration capacity (i.e. large areas will need prompt restoration to reduce the risk of re-infestation)

a Business licence costs: $502 for Inter-Municipal Business Licence if procured through the Township of Langley (Township of Langley, 2020a), or $405 if procured through the City of Abbotsford (City of Abbotsford, 2006).
b Potential permit costs: Township of Langley park permit is $50, required if temporary or permanent structures are erected, or if plants or vegetation are moved (Township of Langley, 2020d). The City of Abbotsford may require a building permit for temporary fencing based on discussions with municipal contacts, and those permit costs are dependent on the cost of construction, and therefore vary (City of Abbotsford, 2020a).
c The City of Edmonton hired a ‘goat coordinator’ who worked part time with an annual salary of $32,500.

Costs to address each logistical component in Table 15 may be additional to the estimated treatment costs outlined in Table 3. Day rates of practitioners may include some of the costs associated with factors identified in this table. To avoid unexpected costs, ensure that practitioner day rates include foundational components such as business licences and permits, transportation, animal husbandry considerations (fencing, night shelters, additional forage if necessary), individual liability insurance, and base camp costs. Ensure that all cost components are assigned in the grazing contract to reduce the potential of additional costs on top of contract costs.

Targeted grazing treatments in Metro Vancouver are only feasible if the logistical considerations outlined in Table 15 can be met, and funding and staff resources have been allocated to support the long-term partnerships necessary for effective control. If treatments are applied ad-hoc and do not meet the recommended timing, frequency, and duration, then control will be ineffective and represent a poor use of financial resources. If treatments can meet these requirements then it is possible to achieve excellent reductions in invasive plant distribution/abundance, and in some cases complete eradication.

Operational Grazing Plan, Field-Testing, and Monitoring

A grazing plan was developed for Aldergrove Regional Park that incorporates treatment of high priority and low priority areas, as deemed by Metro Vancouver Regional Parks staff. The Grazing Plan outlines treatment for 3 years but is organized such that the 'Plan' can be on-going with the addition of 2 new high priority polygons each year and the restoration of 2 polygons each year. The plan is found in detail in Appendix 3.

To understand the impact of targeted grazing on invasive species, and ecosystems in general, a field-testing and monitoring program must be implemented *prior* to the initiation of the grazing plan. The field-testing recommendations and monitoring protocol outlined in Appendix 3 are specific to Aldergrove Regional Park but can easily be transferred to other parks with Himalayan blackberry.

Recommendations For a Pilot Study

Aldergrove Regional Park is well suited for targeted grazing as it includes favourable infrastructure that could easily support a resident goat herd for Himalayan blackberry control. Specific cost estimates for targeted grazing at Aldergrove Regional Park range from $12,000-$56,000 per year based on a review by Tammy Salmon, practitioner quotes from interviews, and frequency and duration requirements from literature review. Cost estimates from literature note that maximum costs for targeted grazing treatment of the target area could range up to $186,600 annually. However, based on conversations with interested practitioners – a realistic annual budget should be $40,000 for a grazing practitioner and $30,000/year for a part-time coordinator.

If Metro Vancouver decides to proceed with a targeted invasive plant grazing pilot study, the following steps should be considered:

- Ensure all steps in Table 15 have been addressed prior to implementation;
- Secure 3+ (preferably 5) years of funding to fully realize potential benefits of targeted grazing;
- Consider hiring a new part time coordinator to ensure contract details are clearly outlined, pre-treatment and post-treatment data is collected, and practitioner activity and deliverables are being met as outlined in the contract;
- Develop an agricultural business support policy; and
- Reach a long-term service agreement with a practitioner.

If logistical considerations cannot be met, and funding and staff resources are not available to properly support the long-term partnerships necessary for effective targeted grazing treatments, a pilot study and field-testing is not recommended. It should be noted that Aldergrove Regional Park is unique and the learnings from such a pilot study may not be transferable to other park settings across Metro Vancouver.

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APPENDIX 1: PRELIMINARTY ASSESSMENT, SPECIES REMOVED FROM SUITABILITY LIST

Parrot's Feather

Parrot's feather (*Myriophyllum aquaticum*) establishes solely in the sediments of waterbodies such as wetlands, streams, reservoirs, ponds, sloughs, etc., preferring warm eutrophic habitats (DiTomaso & Kyser, 2013; Wersal & Madsen, 2011). Although it has been noted that cattle and waterfowl may graze the shoots of parrot's feather (CABI, 2020f) placing livestock in waterbodies has significant logistical challenges and negative consequences on water quality, aquatic habitat, and is likely to result in bank erosion issues. Due to habitat restrictions parrot's feather was deemed unsuitable for control by targeted grazing and removed from this assessment.

Yellow Archangel

Yellow archangel (*Lamium galeobdolon*) has no information available on palatability or toxicity to livestock, or the efficacy of targeted grazing as a control treatment. Although there is no information on grazing impacts, information is available on the impacts of cutting and mowing, which have been shown to increase the spread of yellow archangel as it doesn't remove roots and new growth quickly occurs (Invasive Species Council of BC, 2017b). There is also a risk associated with regeneration from plant fragments (Invasive Species Council of BC, 2017b). Due to the lack of information on grazing efficacy, toxicity, and palatability, in addition to the lack of control from the closest analogue to grazing (cutting and mowing) yellow archangel was deemed unsuitable and removed from this assessment.

Knotweed

Knotweed species of concern in the Metro Vancouver region include Japanese knotweed (*Fallopia japonica*), Bohemian knotweed (*Fallopia x bohemica*), Giant knotweed (*Fallopia sachalinensis*), and Himalayan knotweed (*Polygonum polystachyum, Persicaria wallichii*) (Metro Vancouver, 2019e). All knotweed species are palatable, and in fact are edible for humans (DiTomaso & Kyser, 2013). However, knotweed species spread through an aggressive rhizomatous system, with the ability to re-sprout from stem and root fragments as small as 0.7 grams and buried up to a meter deep (D.J. Beerling et al., 1994). Although grazing may effectively remove above ground biomass it does not address this aggressive root system and may in fact contribute to increased spread as sites have been shown to increase in size following infrequent disturbance due to aggressive re-sprouting (DiTomaso & Kyser, 2013; Invasive Species Council of British Columbia, 2016). Due to low efficacy of targeted grazing for knotweed control, knotweeds were deemed unsuitable and removed from this assessment.

Reed Canarygrass

Reed canarygrass (*Phalaris arundinacea*) is an introduced forage species that has been cultivated across North America (Waggy, 2010b). It prefers sites with moist to saturated soils, often associated with wet meadows, lake shores, streambanks and marshes (DiTomaso & Kyser, 2013; Kercher & Zedler, 2004; Waggy, 2010b). There are varied reports on palatability, with a linkage between increased alkaloid compound concentrations and reduced palatability and nutritional quality (Waggy, 2010b). Reed canarygrass has shown positive responses to disturbance and increased nutrients related to agricultural practices such as grazing (Kercher & Zedler, 2004), and grazing treatments are not successful in reducing abundance (DiTomaso & Kyser, 2013; Hillhouse et al., 2010). Due to low efficacy of grazing as a control treatment, potential toxicity issues associated with alkaloids, and unsuitable habitat (moist soils), reed canarygrass was deemed unsuitable for control by targeted grazing and removed from this assessment.

English Holly

English holly (*Ilex aquifolium*) is an unpalatable and toxic plant, with highly toxic berries containing emetic and purgative toxins, and foliage containing ilicine, ilexanthin, and ilex acid (Severino, 2009). Livestock suffer from nausea, diarrhea, vomiting, and drowsiness from ingesting English holly, with more serious symptoms associated with ingesting large quantities of holly berries (Alsop & Karlik, 2016; Chaney, 2020). Goats and other livestock been known to browse holly foliage, but poor control rates (less than 50% control) have been noted when grazing is applied as a control treatment (DiTomaso & Kyser, 2013). Due to toxicity issues and low efficacy rates, English holly was deemed unsuitable for control by targeted grazing and removed from this assessment.

Yellow Flag Iris

Yellow flag iris (*Iris pseudacorus*) is an unpalatable and highly toxic plant (DiTomaso & Kyser, 2013; Stone, 2009; Tu, 2003). It contains large amounts of glycosides in the foliage and rhizomes, which are toxic to both humans and livestock, and result in abdominal pain, nausea, vomiting, diarrhea, spasms, paralysis, and even death in large doses (Chaney, 2020; Stone, 2009; Tu, 2003). Cattle have been noted to incur gastroenteritis after eating hay containing yellow flag iris (Stone, 2009). Although domestic sheep and fallow deer have been noted to browse early season foliage, it is generally considered a non-forage plant species due to toxicity issues (Alberta Invasive Species Council, 2014; Stone, 2009). Due to toxicity issues yellow flag iris was deemed unsuitable for control by targeted grazing and removed from this assessment.

APPENDIX 2: TARGETED GRAZING DETAILS FOR SUITABLE SPECIES

Giant Hogweed

Palatability

Sheep, goats, cattle, pigs, and horses all eat giant hogweed, but sheep and goats have been found to select for it, preferentially feeding on younger plants but still selecting for older hogweed even when other graminoid forages are available (Buttenschon & Nielsen, 2007; DiTomaso & Kyser, 2013; Tiley et al., 1996). Hogweed is considered to be slightly less palatable to cattle and horses, however they still eat it (Buttenschon & Nielsen, 2007; Lucey, 1994). Animals usually require an adjustment period when introduced to hogweed, but quickly begin to select for it (Nielsen et al., 2005).

Toxicity

Giant hogweed sap contains toxic compounds (furanocoumarins), cause inflammation of skin and mucus membranes when exposed to light (Drever & Hunter, 1970; Gucker, 2009; Morton, 1975; Tiley et al., 1996). Livestock symptoms include blistering, skin lesions, and/or inflammation around the mouth, eyes, ears, nostrils, udders, and genitals, and ongoing hypersensitivity to sunlight, affected animals should be removed from grazing on hogweed (Buttenschon & Nielsen, 2007; Page et al., 2006). Bare, unpigmented skin is highly susceptible to phototoxic dermatitis resulting from hogweed sap, but the selection of livestock with dark pigmentation and thick pelts can mitigate this issue (Buttenschon & Nielsen, 2007; Nielsen et al., 2007; Quinn et al., 2014).

Hogweed also contains flavonoids, glycosides and essential oils in addition to furanocoumarins, and a single case of suspected poisoning of an African pygmy goat by hogweed has been recorded, indicating that there may be some potential toxicity issues if large amounts of hogweed are ingested, however this was determined through circumstantial evidence and the illness may have resulted from another cause (Andrews et al., 1985).

Grazing Timing and Frequency

Grazing should begin mid-spring to take advantage of increased efficacy associated with grazing small plants, resulting in the depletion of nutrients and resources stored in taproots (Buttenschon & Nielsen, 2007; Gucker, 2009). An approach of high stocking rates in the spring, followed by another grazing treatment in the summer with lower stocking rates provides highly effective control (Buttenschon & Nielsen, 2007; Nielsen et al., 2005).

Dense stands should receive heavy grazing pressure repeated throughout the growing season to exhaust root stores and take advantage of tender regrowth, and repeated over years to eradicate existing plants and any germinating plants from the seed bank (Buttenschon & Nielsen, 2007; Gucker, 2009). Seed bank studies have found that giant hogweed seeds can persist for a 5-6 years prior to germination (Andersen & Calov, 1996; Andersen, 1994; Krinke et al., 2005). A timespan of 10 years of grazing treatments has been suggested to ensure total eradication, but 7 is suggested in this report based on seedbank viability (Andersen & Calov, 1996; Nielsen et al., 2005; Williamson & Forbes, 1982).

Digestive Efficiency

There is no currently available literature on the digestive efficiency of giant hogweed seeds by livestock, however studies on other plant species (leafy spurge) have shown fewer viable seeds recovered from domestic herbivores relative to other animals, and the more complex and efficient digestive systems of ruminant livestock are likely to have higher rates of digestive efficiency for giant hogweed seeds (Frost & Launchbaugh, 2003; Ingham, 2008; Lacey et al., 1992).

To mitigate the potential for endozoochorous seed spread animals should be penned for 3-4 days prior to moving on to other pastures (Buttenschon & Nielsen, 2007; Frost & Launchbaugh, 2003).

Off-Target Effects

Grazing is likely to influence other plant species within the target area, and studies have shown that eradication of giant hogweed through grazing is accompanied by an overall decrease in species diversity (Andersen & Calov, 1996; Lashley, 2016). Grazing treatments will suppress the abundance of plant species less tolerant of grazing pressure, and encourage dominance of grazing tolerant species (Lashley, 2016). Grazing may result in soil compaction or erosion issues, but this can be mitigated by timing grazing with dry soil conditions.

Suitable Livestock Control Options

Sheep, goat, cattle, and pig grazing has been associated with effective hogweed control (Andersen & Calov, 1996; Tiley et al., 1996; Wright, 1984). Sheep, goats and pigs are all associated with effective control, and pigs are able to disturb and pull out deep taproots through rooting behaviour (Tiley et al., 1996). Sheep and goats seek out hogweed, and many breeds have the physiological attributes (dark pigmentation, thick pelts) that reduce susceptibility to phototoxic dermatitis (Buttenschon & Nielsen, 2007; Nielsen et al., 2007; Quinn et al., 2014). Control efficacy and mitigation of potential negative impacts on livestock is achieved by using grazing animals experienced with giant hogweed, or pairing inexperienced animals with experienced animals (Buttenschon & Nielsen, 2007).

Sheep have been considered to be the most effective livestock for controlling hogweed, although studies to date have not included goats (Andersen & Calov, 1996; Andersen, 1994; Page et al., 2006). Due to documented success with sheep, and physiological and dietary similarities, goats and sheep are considered the most suitable livestock species for giant hogweed control in Metro Vancouver Regional Parks.

English and Irish Ivies

Palatability

Despite the presence of secondary compounds and mild toxicity, ivy is considered a highly palatable species for both livestock and wild ungulates (Ingham & Borman, 2010; Jozo et al., 2018; Van Uytvanck & Hoffmann, 2009). Roe deer will select for ivy to the point where it may compose their primary forage (Jackson, 2009). Both goats and cattle have been shown to preferentially select for ivy even when other forage is available, indicating a high level of palatability (Ingham & Borman, 2010; Jozo et al., 2018; Van Uytvanck & Hoffmann, 2009).

Toxicity

Ivy contains hederin, a mildly toxic saponin secondary plant compound, in foliage and berries (Jozo et al., 2018; Strelau et al., 2018; Waggy, 2010a). Ingestion of large quantities of ivy can have adverse effects on livestock, including vomiting, diarrhea, muscular weakness, staggering, spasms, and even paralysis (Chaney, 2020; Strelau et al., 2018; Waggy, 2010a). Often secondary compounds will result in suppression of forage intake and render the plant unpalatable to grazing animals (Cheeke, 1998). However, ivy has been noted as palatable to livestock, and will consume large amounts of ivy despite the potential toxicity issues (Ingham & Borman, 2010; Jozo et al., 2018; Van Uytvanck & Hoffmann, 2009).

Animals that have training and prior experience with ingesting secondary compounds will readily consume large amounts of ivy (Distel & Provenza, 1991), and animals that are part of a herd trained to consume the target plant will learn from their herd mates to eat it (Ingham, 2008). Providing high protein feed before ivy grazing will increase intake and reduce impacts of secondary compounds on goats (Ingham, 2008). A dietary supplement of tannins may help reduce the effects of ivy toxicity on goats (Rogosic et al., 2006).

Grazing Timing and Frequency

There is flexibility in timing of grazing treatments with ivy, it is well adapted to a large range of climatic conditions and will still actively grow in low moisture and low light conditions (Sack, 2004; Strelau et al., 2018). This flexibility can allow for effective grazing treatments under favourable dry soil conditions, such as late summer. Care must be still be taken to ensure that grazing treatments occur when plants are still actively growing to maximize grazing impact and efficacy (Ingham, 2008).

To be effective grazing treatments should be repeated once a year for at least two years to reduce the bulk of ivy cover and biomass, and include a monitoring plan along with follow-up treatments as needed to prevent ivy recolonization (Frey & Frick, 1987; Ingham & Borman, 2010; Van Uytvanck & Hoffmann, 2009).

Digestive Efficiency

Ivy seeds are highly viable and borne in the berries of the plant (Strelau et al., 2018). Seeds actually require scarification of their seed coat to enable germination, and this role is generally fulfilled by birds who eat berries, which pass through their digestion system, are scarified by the digestion process, and then dispersed (CABI, 2020b; Okerman, 2000; Reichard, 2000). There is no currently available literature on the digestive efficiency of ivy seeds by livestock, however studies on other plant species (leafy spurge) have shown fewer viable seeds recovered from domestic herbivores relative to other animals, and the more complex and efficient digestive systems of ruminant livestock are likely to have higher rates of digestive efficiency for ivy seeds (Frost & Launchbaugh, 2003; Ingham, 2008; Lacey et al., 1992).

Off-Target Effects

Grazing may result in soil compaction or erosion issues, but this can be mitigated by timing grazing with dry soil conditions (Heitschmidt, 1990; Ingham & Borman, 2010). Off-target grazing of desirable native species is a potential side-effect of targeted grazing for ivy (Ingham & Borman, 2010). Goats have been found to damage trees in some cases through browsing and bark stripping (Wood, 1987).

Ivy removal has been associated with temporary disturbance of native plant communities, but native plants were shown to overcome disturbance and recolonize in as little as ten weeks following ivy treatments (Stanley & Taylor, 2015).

Suitable Livestock Control Options

Cattle and goats have both been used for targeted grazing of ivy with high levels of efficacy, and sheep have been linked to the prevention of ivy spread (Ingham & Borman, 2010; Metcalfe, 2005; Van Uytvanck & Hoffmann, 2009)

Due to ease of handling and documented success, goats are considered the most suitable livestock species for ivy control in Metro Vancouver Regional Parks.

Himalayan Balsam

Palatability

Sheep, cattle, and horses have all been noted to select for Himalayan balsam (Beerling & Perrins, 1993; Helmisaari, 2006; Larsson & Martinsson, 1998; Pacanoski et al., 2014). However, Matthews et al. (2015) has asserted that grazing animals will select for other plants before turning to Himalayan balsam, but noted that sheep may be more effective as they are less selective grazers.

Toxicity

There is no known toxicity associated with Himalayan balsam (CABI, 2020d; Clements et al., 2008)

Grazing Timing and Frequency

Grazing during early spring, prior to seed release, with repeated treatments throughout the growing season and in subsequent years has been shown to be the most effective approach to reducing spread and infestation size of Himalayan balsam (Clements et al., 2008; Čuda et al., 2017; RAPID, 2018).

Grazing treatments must be repeated over two years to ensure that infestations are eliminated by addressing seedbank longevity, and if grazing coincides with seed release it does have the potential to increase seed transport and spread the infestation (Čuda et al., 2017).

Digestive Efficiency

There is no currently available literature on the digestive efficiency of Himalayan balsam seeds by livestock, however a study using mallard ducks found 100% efficiency, with no seeds retrieved after passage through the ducks (Kleyheeg et al., 2015), and another using fish found high rates of digestive efficiency (>80%) (Boedeltje et al., 2015). It is not unreasonable to assume that the more complex and efficient digestive systems of ruminant livestock would have higher rates of digestive efficiency for Himalayan balsam seeds than fish and waterfowl.

Off-Target Effects

There is a concern that grazing in riparian areas or on steep slopes may create additional bare soil and vector points enabling the propagation and spread of Himalayan balsam (Cockel & Tanner, 2011; RAPID, 2018). However, this should be considered within the context of bare soil associated with existing Himalayan balsam monocultures when the plant dies back annually (CABI, 2020d; Clements et al., 2008).

There is a concern that livestock may trample sensitive riparian soils when grazing Himalayan balsam, resulting in pugging and hummocking of moist soils with potential subsequent impacts on water quality and aquatic habitat (RAPID, 2018).

Suitable Livestock Control Options

Effective control has been associated with cattle, horse, and sheep grazing (Clements et al., 2008; Helmisaari, 2006; Larsson & Martinsson, 1998). Sheep have been noted as good control options as they crop vegetation close to the ground, which removes Himalayan balsam plants below their lowest node and prevent regrowth and flowering (Matthews et al., 2015; RAPID, 2018). Goats have a similar grazing pattern and would be as effective as sheep.

Due to their large size and the nature of Himalayan balsam habitat (moist ground) cattle are not considered a suitable option due to the potential negative impacts of trampling and pugging/hummocking of sensitive soils (RAPID, 2018). Sheep and goats are smaller and lighter, and as such better options for control of Himalayan balsam in Metro Vancouver.

Himalayan Blackberry

Palatability

Himalayan blackberry is considered highly palatable to goats, who will select for it year round, and is also readily consumed by sheep, horses, and pigs (King County, 2014; Meat & Livestock Australia, 2007; Milliman, 1999).

First year canes are considered the most palatable, while second year and older canes are less palatable. In cases where there are other foraging opportunities, goats may not consume second year canes (Ingham, 2008). Milliman (1999) noted that sheep found Himalayan blackberry palatable as they selected for it even in low intensity grazing treatments where other forages were available.

Toxicity

There is no known toxicity associated with Himalayan blackberry (CABI, 2020g; Tirmenstein, 1989).

Grazing Timing and Frequency

Himalayan blackberry growth is concentrated in spring and early summer, and grazing during these periods coordinated with the onset of flowering is more effective as it removes stems with considerable nutrient storage resource and meristematic tissues, effectively reducing vigour and the ability to regrow (Ingham, 2008). This timing also coincides with dry soil conditions which can reduce potential negative impacts related to trampling and erosion (Hendrickson & Olson, 2006; Ingham, 2008).

Repeated grazing yields better control results that single treatments, two treatments in the same growing season occurring over two years has been associated with enhanced efficacy (Hendrickson & Olson, 2006; Ingham, 2008).

Bennett (2006) noted that goat grazing is best suited for control of Himalayan blackberry when

1. An initial mechanical treatment is applied and goats are used to graze regrowth
2. Browsing occurs over the entire growing season
3. The treatment is applied over 2 or more growing seasons
4. Desirable woody vegetation can be protected/controlled, or browsing of it is not an issue

Digestive Efficiency

Concerns around the spread of seeds following berry consumption have been raised, with some literature noting that seed dispersal by birds and omnivorous mammals such as bear, coyote, foxes and rodents have been shown to contribute to the spread of Himalayan blackberry (Hoshovsky, 2000; Soll, 2004). There are currently no available studies relative to digestive efficiency or spread by domestic livestock, however their more complex digestive systems are likely to reduce seed viability following digestion and reduce endozoochorous spread relative to birds and omnivorous mammals.

Off-Target Effects

Grazing treatments for Himalayan blackberry are indiscriminate in nature and may result in impacts to off-target vegetation (DiTomaso & Kyser, 2013). Goats have been found to damage trees in some cases through browsing and bark stripping (Wood, 1987). Other studies have noted that targeted grazing treatments resulted in very little damage to other vegetation, even as new plants were becoming established (McGregor, 1996).

Removal or reduction of the blackberry canopy is immediately beneficial for other plant species as light resources become available (Ingham, 2008). Substantial increases in grass production have been noted with the removal of blackberry thickets (McGregor, 1996).

Suitable Livestock Control Options

Most livestock will eat blackberry fruit and leaves (Ensley, 2015), but goats have been shown to readily eat berries, leaves, and canes, with declines in seedling densities attributed to berry consumption (Ensley, 2015; Ingham, 2008). Goats will select for blackberry year-round, and have prehensile tongues, allowing them to easily consume the palatable portions of blackberry plants (Campbell & Taylor, 2006; Meat & Livestock Australia, 2007). Sheep will also preferentially select for blackberry (Milliman, 1999). A study by Magadlela et al. (1995) noted that sheep took 3 years to reduce brush cover (dominated by blackberry) to the same level as goats did in one year of treatment, but both goats and sheep reduced cover to 2% after five years of treatment.

Goats tend to prefer brush to grass and are more suited for control of blackberry, however sheep are less likely to damage trees through browsing or bark-stripping than goats (Wood, 1987).

Pigs will consume both canes and leaves of Himalayan blackberry, and will root the earth to disturb root systems, but represent significant challenges relative to public relations and issues relating to manure odours (King County, 2014). Additionally, there is a risk associated with feral pigs if escape occurs.

Cattle are not considered a suitable species for Himalayan blackberry control, their grazing presence has been associated with further spread and colonization of Himalayan blackberry (Cousens & Mortimer, 1995; Ingham, 2008; Krueger et al., 2014).

Goats and sheep are considered the most suitable livestock species for Himalayan blackberry control in Metro Vancouver Regional Parks.

Purple Loosestrife

Palatability

Mature purple loosestrife is generally not considered palatable to most animals, although young shoots are considered palatable to livestock and grazing wildlife (King County, 2011; Louis-Marie, 1944; Reinbrecht, 2017). Despite this assertion, studies reviewing targeted grazing have shown considerable grazing impact on loosestrife by sheep, goats, and cattle, indicating that the plant is not unpalatable, and noting that is palatable to goats (Kleppel & LaBarge, 2011; Tesauro, 2001; Tesauro & Ehrenfeld, 2007).

Toxicity

There is no known toxicity associated with purple loosestrife (CABI, 2020e; Mal et al., 1992; Munger, 2002).

Grazing Timing and Frequency

Grazing during the growing season is considered the most effective approach, and successful reductions in loosestrife abundance were noted with grazing treatments occurring over June to August (Kleppel & LaBarge, 2011; Tesauro & Ehrenfeld, 2007).

Loosestrife reproduces from both root fragments and by seed, so grazing treatments would need to be repeated annually to exhaust root reserves, and to ensure that any new germinants are controlled, with consideration to a robust seed bank that retains viability for at least 3 years (CABI, 2020e; Invasive Species Council of BC, 2017a; Munger, 2002; Welling & Becker, 1990).

Digestive Efficiency

There is no currently available literature on the digestive efficiency of purple loosestrife seeds by livestock, however seed dispersal and spread is associated with waterfowl consumption and excretion, although there is no direct evidence (Thompson et al., 1987). It is not unreasonable to assume that the more complex and efficient digestive systems of ruminant livestock would have higher rates of digestive efficiency than waterfowl.

Off-Target Effects

Purple loosestrife is found primarily in riparian areas and other habitats with moist soils in the Metro Vancouver region, and grazing livestock have the potential to negatively effects moist soils through trampling (Alberta Environment and Parks, 2019a; Metro Vancouver, 2020a). Grazing on moist and saturated soils can result in the reduction of plant cover, soil compaction, degradation of aquatic habitat, and pugging/hummocking of soils (Alberta Environment and Parks, 2019b).

These potential impacts should be weighed against the benefits of reducing loosestrife infestations, and the innate resiliency of riparian systems, which are able to revegetate relatively quickly due to ideal growing conditions.

Suitable Livestock Control Options

Good control has been associated with cattle, sheep, and goat grazing of loosestrife (Kleppel & LaBarge, 2011; Tesauro, 2001; Tesauro & Ehrenfeld, 2007). Cattle are larger and heavier, which increases the potential for negative off-target effects.

Seeds can be carried by sheep wool, and the introduction of loosestrife to North America is partially attributed to seeds carried in sheep wool to the eastern coast, so animals that do not have a densely wooly coat should be selected for grazing treatments (Stuckey, 1980). Kleppel & LaBarge (2011) used Romney sheep in their loosestrife control trials, selected for their docile nature, adaptation to temperate climates and hardy nature relative to moist soils and poor pasture quality. Goats will tend to avoid moist areas as they dislike getting wet, and particularly avoid wet feet, although Kiko goats appear to be better able to handle wet conditions (Salmon, 2020).

Goats and sheep are considered the most suitable livestock species for purple loosestrife control in Metro Vancouver Regional Parks.

Scotch Broom

Palatability

Scotch broom is considered unpalatable to most livestock with the exception of goats (DiTomaso & Kyser, 2013). Mature foliage is considered less palatable than younger shoots and stems, however Scotch broom has been reported as highly palatable and preferentially selected for by sheep and goats in Australian and New Zealand trials (Meat & Livestock Australia, 2007; Pande et al., 2002).

Despite the presence of mild toxicity due to quinolizidine alkaloids, Scotch broom contains a good nutritional profile with high levels of crude protein, representing a high quality forage (Ammar et al., 2004; DiTomaso & Kyser, 2013).

Toxicity

Scotch broom seeds and flowers contain quinolizidine alkaloids, which are mildly toxic to livestock, and foliage contains these same compounds in smaller amounts (Chaney, 2020; DiTomaso & Kyser, 2013). These compounds can result in nausea, vomiting, and dizziness (Chaney, 2020).

Livestock poisoning has been reported in Europe, but very rarely in North America (Graves et al., 2010). Toxicity has not been reported in goats or llamas (Graves et al., 2010).

Grazing Timing and Frequency

For the highest levels of control, grazing should be high duration and high frequency, as the removal of grazing pressure is associated with a rapid return of Scotch broom (Álvarez-Martínez et al., 2016; Bellingham & Coomes, 2003; Meat & Livestock Australia, 2007). Heavy grazing for the duration of the growing season over 4 or 5 years is reportedly effective for eradication of Scotch broom, although this is in combination with other treatments, such as grazing, as a component of ongoing integrated weed management (Álvarez-Martínez et al., 2016; Zouhar, 2005). Grazing during active growth shows better control, but still requires season-long application over several years for effective control, and commencing grazing in early spring to weaken plants is the most effective approach (Zielke et al., 1992).

Digestive Efficiency

Scotch broom seeds have hard coats that function to delay germination and enable seed banking, which also act to protect them from digestive functions (CABI, 2020a; Zouhar, 2005). A study reviewing digestive efficiency of Scotch broom seeds by goats found that 8% of seeds remained viable following ingestion, representing a potential for endozoochorous spread (Holst et al., 2004).

Off-Target Effects

Goats and other livestock are non-selective and will graze on off-target species, with potential negative impacts on native plant communities interspersed within Scotch broom infestations (Bossard, 2000). Removal or reduction of the Scotch broom canopy is immediately beneficial for other plant species as light and nutrient resources become available.

Suitable Livestock Control Options

Sheep and goats have been noted as effective livestock for the suppression of Scotch broom, with meat goats highlighted as the most effective option (Odom et al., 2003; Rousseau & Loiseau, 1982). Sheep and goats will both consume Scotch broom stems and flowers, and tender new growth/shoots, but goats will also strip bark during the winter (Holst et al., 2004). Sheep will browse plants up to 90cm in height, while goats will browse up to 120cm, and goats are associated with a greater impact on Scotch broom vigour and health than sheep (Holst et al., 2004). Sheep will also begin to select for other pasture species once they become available, while goats will continue to select for Scotch broom (Holst et al., 2004). Other studies have noted that sheep would not eat Scotch broom (Zielke et al., 1992).

Larger grazing animals such as cattle have been associated with reduced Scotch broom biomass, but this effect is primarily through trampling as cattle exert very little to no grazing pressure on Scotch broom, allowing infestations to persist within cattle paddocks (Hosking et al., 1998; Odom et al., 2003). In some cases cattle grazing has actually been associated with the spread of Scotch broom (Hosking et al., 1998). Llamas have shown some success in California trials, but are not readily available for targeted grazing in B.C. (Graves et al., 2010).

Goats and sheep are considered the most suitable livestock species for Scotch broom control in Metro Vancouver Regional Parks.

Wild Chervil

Palatability

Wild chervil is palatable when young (although not as palatable as grasses and other forbs), and once it matures it is considered unpalatable to livestock and they will avoid it (Bosworth, 2012; DiTomaso & Kyser, 2013; Invasive Species Council of BC, 2019; Province of British Columbia, 2002). It is considered especially palatable in the rosette stage, but it is important to note that it is low in nutritional value, and care should be taken to ensure livestock nutritional requirements are being met in cases where wild chervil composes a significant portion of their diet (Darbyshire et al., 1999; Hansson & Persson, 1994; Wagner, 1967).

Toxicity

There is no known toxicity associated with wild chervil, although it has been noted to occasionally cause skin irritation in people (Bosworth, 2012; Darbyshire et al., 1999; King County, 2018)

Grazing Timing and Frequency

Early season grazing is correlated with reductions in wild chervil populations, where grazing during spring growth will work to reduce root reserves and exhaust plants, ultimately causing mortality (Darbyshire et al., 1999; Wagner, 1967). Grazing in fall will have little impact on wild chervil populations as they have already completed their reproductive cycle and begun the reallocation of resources to taproots (Hellström et al., 2003).

Wild chervil reproduces both vegetatively and by seed, so grazing treatments would need to be repeated annually to exhaust root reserves and ensure that any germinants are controlled (Darbyshire et al., 1999; van Mierlo & van Groenendael, 1991). Chervil seeds are short-lived (1-2 years) and do not form a persistent seed bank, any treatments should be at least 2 years in duration to address this seedbank (van Mierlo & van Groenendael, 1991).

Digestive Efficiency

There is no currently available literature on the digestive efficiency of wild chervil seeds by livestock, seed dispersal and spread is associated with epizoochorous (dispersed by adhering to animals) rather than endozoochorous methods (Couvreur M., 2005). Other studies have noted high levels of digestive efficiency of hard coated seeds (Scotch broom with 8% viability, leafy spurge with 18%) in ruminant livestock, and it is not unreasonable to assume that wild chervil seeds, which do not have a hard coat, would have lower levels of viability than hard coated seeds after passing through the digestive tracts of ruminant livestock (Frost & Launchbaugh, 2003; Holst et al., 2004; Lacey et al., 1992).

Off-Target Effects

Grazing is likely to influence other plant species within the target area, and studies have shown that eradication of wild chervil through grazing is accompanied by an overall decrease in species diversity (Andersen & Calov, 1996; Lashley, 2016). Grazing treatments will suppress the abundance of plant species less tolerant of grazing pressure, and encourage dominance of grazing tolerant species (Lashley, 2016). Highest efficacy of grazing treatments is associated with early season spring grazing, which may result in soil compaction or erosion issues associated with grazing on moist soils (Alberta Environment and Parks, 2019b).

Suitable Livestock Control Options

Cattle, sheep, and rabbits have been noted to consume wild chervil, and are associated with declines in chervil abundance or suppression of spread into grazed pastures (Darbyshire et al., 1999; Hansson & Persson, 1994; Hellström et al., 2003; Pavlů et al., 2007; Wagner, 1967).

Due to ease of handling and herd availability, goats are considered the most suitable livestock species for wild chervil control in Metro Vancouver Regional Parks.

APPENDIX 3: PRACTITIONER INTERVIEWS

Interview Questions	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11	Practitioner 12	Practitioner 13	Practitioner 14
Company/Individual:	Creekside Goat Company Robert Finck-Owner	Vahana Nature Rehabilitation Cailey Chase-Owner	Goats on the Hoof Beverly Ness/Allan Iwanyshyn	BC Timber Goats Bruce Bradley	Thorcrest Farm Purebred Nubian Zoe Thorbergson-Acting President, BC Goat Association	RR Savannah - Range Ready Goats Joy Hurlburt, Hurlburt Ranch Ltd. Box 1119 Fort McLeod AB	Natasha Murphy	Lee Sexton Hanley, Saskatchewan	Healing Hooves, Craig Madsen PO BOX 148 Edwall WA, 99008	Goats Unlimited Kikos An Peischel, Masters and Ph.D in Range Livestock Nutrition Tennessee	The Aveley Ranch, Vavenby BC Valerie Moilliet-Gerber	Rocky Ridge Vegetation Control Conrad Lindblom Retired with 25 years exp.	SXDC Ltd Clayton Harry, General Manager	The Canny Crofter Jayne D'Entremont
Experience:			2014- Present		* would like copy of report for BC Goat Association website as a resource, contact info etc. for people searching graziers-she gets lots of inquiries			**23 years exp with sheep and 9 years with goats. Ranching management style		***35 years of experience using goats for land enhancement, Hawaii, California, Tennessee	**4th Generation Sheep Ranchers since 1913	*willing to do presentation to groups, promotion, power points, lots of photos and practical experience in a variety of circumstances	In start-up, training phase, available for contracts 2021	Experience working on private rural properties
Website	N/A	www.vahana.ca	www.goatsonthehoof.com	www.bctimbergoat.ca	www.thorcrestfarm.ca	N/A	N/A	N/A	www.healinghooves.com	goatsunlimitedkikos.com	aveleyranch.com			www.cannycrofter.ca
General Area Serviced: (e.g. Fraser Valley, Southern Interior, etc.) Where else are they working - other contracts? Years worked there if recent	Southern Alberta-Medicine Hat, Calgary, Lethbridge	Cranbrook, Kimberly, Grassmere, Calgary AB	Central Vancouver Island-Campbell River to Duncan, Earth Day in Esquimalt	Quesnel, Prince George, North Okanagan.	N/A	Southern Alberta, home ranch (3,400 acres with 12 miles of river frontage + year round springs) and neighbors properties	East Kootenays, Tobacco Plains, Invermere, Logan Lake. Worked with Conrad Lindblom	All in Saskatchewan. Developed 3 year targeted grazing project in Federal Government Community Pasture comprising 3,200-4,200 head of sheep and goats for leafy spurge	Washington, Northern Oregon for 18 years with sheep and goats Grazing Season in Washington is June-Oct (some practitioners start in April)	Hawaii, California, Tennessee	North Thompson, BC. Silviculture contracts with forestry	BC/ALBERTA. Logging blocks, wetlands (Logan Lake), semi arid, pasture improvement, power lines, demos (Fraser Valley on knotweed, Logan Lake on purple loosestrife).	Quesnel, Williams Lake area	Barriere BC-own farm and neighboring farms, tends to rent out small numbers of her herd to farmers who are willing and trained to supervise, put goats in shelter at night etc.
Willing to work in Metro Vancouver?	****very interested in working in Vancouver to extend to year round work for goats	**interested in working in Vancouver, availability end of July-Oct or later as needed	*Do not want to travel outside of their area, very supportive of growth in industry	** selling herd July 2020 and moving to Vancouver Island	No	No	*ecological restoration-SFU, Science-BCIT, would be willing to assist with monitoring	No	No	No	No	N/A	Potentially, depending on how the contract compliments their current operations	No
Livestock Type: goats/sheep/both	Goats: Spanish/boer X (sheep, cattle and any other livestock as required)	Cashmere goats (aka Spanish goats)	Goats: Nubian/boer/Saanan crosses (very tall)	Goats, Kiko/Kiko X	N/A	450 Savannah Goats Cows-commercial and purebred	Goats	Goats, sheep and cattle on own ranch	Goats only	Goats-Kikos, Biocontrol	Sheep	Goats	Goats	Goats and Sheep
Herd Size:	Goats: up to 400 head	230	11	120	N/A	Separated into 3 herds based on age and sex	5 at the moment-goal is to have a herd of 50	500 Spanish cross goats grazing private ranch contracts	200-220	100-1,500	1,300	100-1000	200	80 Goats: mixed herd of 35 does plus kids to total 60 Sheep: (Icelandic) of 12 ewes and 11 lambs
Do they have experience with the Priority Weeds for MV?	No, experienced with leafy spurge, white top, thistle	NO. 4 grazing seasons with: Spotted knapweed, blueweed, Dalmatian toadflax, sulphur cinquefoil, Canada Thistle, yellow clematis, creeping bellflower, leafy spurge, yellow hawkweed, common snowberry bush, Western snowberry bush, rose bush	Yes, Blackberry, Scotch Broom, English Ivy	No. Original experience was in Ontario with Knotweed, Phragmites, Sumac, Shoreline remediation/reclamation Noted that goats love "viney" plants	Limited experience on own farm and anecdotal knowledge	No, use goats to manage a 30 acre gravel pit to keep it weed free for audits- blueweed, bladder campion, clover, willow, kochia	Yes: English Ivy, Himalayan Blackberry, and Scotch Broom Also: Knapweed, sulphur cinquefoil, morning glory	Not personally but have heard they are effective for blackberry and purple loosestrife	Yes	Yes	No	Yes, Blackberry, 1 demo day on Purple Loosestrife for BCIT	No. Prefer brush control, fire mitigation contracts	No

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Herd Rental: (Rented by treatment area? Treatment days? AUMs?)	Generally charges by the day, approximately $1000/day, very site/job specific. Would prefer to charge by the acre with allowance for grazier to decide management and grazing schedule	Depends on job site, $1000-1200 per day (Kootenay region), $2000/day in large cities (requires more management) and it includes transport, water etc.	Contract price based on site, $150/day Self contained unit for maximum of 10 days, prefers 5-7 day and has a minimum requirement of 2 full days	Based on daily operation costs, approx. $1100/day	N/A	N/A	Site dependent, density and species dependent	Prices according to the site and contract requirements. All inclusive price PLUS transportation costs on top, requires water to be provided by contracting agency. Usually bids a daily price and allows for flexibility on number of days	Varies-depends on project and client requests, and occasionally by $'s allocated by contracting agency	Depends on project after initial vegetative sight analysis - day/month/project /animals by the day options. Needs to know specifics of the site	Charged on a per hectare basis, costs increase for difficult accessibility sites	N/A	Contract dependent, prefer day rate billing for consistency	Bases cost on treatment days depending on site attributes and how much additional labor is involved for her and goats to be on site safely
Staff: (Is there a minimum number staff days required to support work?)	At least one staff on site 24 hours/day. Currently 2 shepherds and one trainee on 8 month retainers, seasonal training done during kidding Jan-March.	1 on site 24/7, currently working with a grant for summer student-8 hours per day, Part-time high school student, daily rate for apprenticeship couple. Training is costly and time consuming	2 staff required for transport and set up, 1 on site 24/7	need minimum 2 people for job sites, transport and set-up/take down, supply runs etc.	N/A	1-2 people at all times. Ideally 3 full time	2 staff currently on site, will be site and contract dependent	Usually just one person (himself), herding dogs and horse	One person operation with 2 herding dogs and 1 livestock guardian dog	Requires assistance with electric fence-3-4 people depending on project Prefers to manage her own herd with good herding dogs	If area is fenced, 1 person with dog In range areas 1-3 people each with their own dog	N/A	2 plus herding dog	She has her own multi-species farm so requires someone at home and on grazing site
Infrastructure: (Fencing, corrals, heat/rain shelter, etc. - cost per treatment)	Night penning in portable fence panels, electric net fencing as needed, stock are range hardy Try to night pen in as much shelter (trees) as possible, night pen is moved as often as required to keep animals comfortable	Night pen in wire hog panels with T-posts (VERY labor intensive) transitioning to electric netting. Using electric lunch pen at far end of contract site, working goats from end to end in a day. Shade/trees for night pen is appreciated. Goats are range hardy	Electric netting fence, shade/rain gazebo plus tarping as required	150 - 4x7 portable panels for night pen	N/A	Permanent fencing Range Ready = no barn, moveable calf shelters	Portable panels and trailer for night pen	Electric netting for paddocks	Electric net fencing	Electric net fencing	No fence required for their own flock If community flock (multiple owned flocks) then use night pen	N/A	In process of acquiring	Currently only chooses sites that have infrastructure to support needs of goats (ie. Shelter, water and fencing). Does use electric netting as necessary.
Water: (Hauling, water pump costs, etc.)	Site and job dependent, cities usually provide tank and haul water or pump from accessible river etc.	Appreciate if cities provide so herders can stay in camp and don't have to travel to pump water but it is included as part of daily rate	Self sufficient with tanks but appreciates if homeowner or hiring agency supports water supply	Pump or haul as required by site	N/A	Winter hauling only to date as goats access river during 3 seasons. Now changing to a frost free solar system for year round water access	Currently able to access on sites	Provision by contracting agency required to allow grazier full attention to herd management	Bidding includes access to water (in urban areas there is always irrigation or ponds or a tap)	Prefers to have water hauled and doesn't rely on any natural water bodies on site	Haul tank with trough and float valve, or on the range	N/A	Use forestry tanks on trailers as required	Currently water is provided at site by hose
Transportation: (Costs for transporting herd)	26 ft double deck trailer to transport 200 hd for local sites, stock hauler (400 hd+) increases costs for long hauls and larger herd sizes	Hired hauler with truck and trailer - $70/hour In the early days of the business volunteers - gas cards, to move entire herd takes 2X30 ft trailer+16 foot stock trailer, truck and camper	RV with garage, stock trailer, should separately charge for mileage and fuel costs but doesn't	N/A	N/A	N/A Active herding in local areas…take goats for a walk!	Truck, trailer, fuel and FERRY FEES	Usually a semi truck, or owns a stock trailer that hauls 140 goats for smaller contracts	Adds trucking to bid costs	Depends on distance/project	Usually just work in their area and herd to location	N/A	Intend on cattle hauler to facilitate one trip and reduce hauling costs	Time and fuel

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Vehicle(s): How many vehicles do you use to transport livestock? What make/model/fuel type do you use for your vehicle(s)?	N/A	N/A	N/A	30 ft gooseneck stock trailer, 5th wheel trailer, 3/4 tonne truck (takes multiple trips to set up entire herd - very time consuming and expensive for long trips)	N/A	N/A	2005 Dodge Ram diesel truck and stock trailer	Two 3/4 ton trucks- one diesel, one gas, stock trailer, travel trailer	Semi with sleeper and stock trailer	Truck with chute, fence panels, and 24 ft double deck stock trailer, truck and camper	N/A	N/A	See above	1 truck and trailer or just truck with canopy on back, takes fewest numbers possible to eliminate need for high transportation costs
Generator: Do you use a generator at camp? Approximately how many hours a day? Make and model	N/A	N/A	N/A	N/A	N/A	N/A	Not currently Battery and solar for fencing and trailer	No. Use solar and battery or plug in if accessible	No, 12 Volt system	N/A	No	N/A	Not sure at the moment	No, Able to use truck and camper if required
Liability Insurance:	Yes, $ 5 million required by City of Calgary	Yes, $5 million approximately $1000/year, This cost increases as income increases	Yes, $5 million. Approximately $1000/year	No	N/A	N/A	Not currently	Yes. $2 Million	Yes. Commercial Liability $1 million	Yes-and carries at least $2 million on each Large Guardian Dog	N/A	N/A	Yes, through ranch coverage	Not needed yet as covered by farm insurance
Additional Costs:	Self contained unit with staff accommodations and on-site generator	Fluctuating gasoline costs are prohibitive for long and or frequent transport	Winter feed costs and goat health maintenance, hoof trimming etc., vaccines, requirements for multiple business licenses or an "inter community" license	Drone- used very effectively for herding on steep hillsides and large areas	N/A	Guardian dogs $1000 each. Herding dogs- $2500 each. Feed, vet cost- Vaccine, dewormer, tagging ID (triple tagged) = $15-20/head/year	Information signage for public pedestrian and traffic control	No	Washroom facilities (port-a-potty rental) some urban sites might need additional security based on location	Dogs for predator control are expensive to run and should be factored into costs, require "beware of dog" warning signs every 300ft on electric fence	Extra costs for any fencing requirements and additional labor	N/A	Vet expenses	Horses on more rugged terrain and associated fencing and transport costs
Age and sex? Mixed age herd? Weanlings? Wethers?	Mixed age, closed herd	Mixed ages, does with weanlings and wethers.	3 wethers, 9 does, age 6+, keep all until death, no breeding , positive PR as folks get to know individual goats * no one wants billies in the city because of the smell	Mixed age, does and kids Would be beneficial to run a wether herd if early spring grazing was required so no transport of kids	N/A	ALL - divided into 3 herds, older does, 1-2 year old doelings, wethers and billies	Wethers, and 1 doeling Will continue to add more wethers	Mixed age, keeps wethers for I year (overwinters)	Mixed herd, does, kids, and wethers	Prefers to run dry does and wethers for weed control	Mixed herd	N/A	Mixed age and sex	Mixed herd
Kidding on Site	No	No	No	No	N/A	Kidded out 180 this year. Recommends no kidding on any city site-due to high mortality rate=negative PR!!! Kids in April/May on the range	No. Recommends to avoid Kidding on site for PR	if Yes it is prearranged with contract agency (i.e.. on leafy spurge 20% protein in May-June for 3 weeks)	No	No	No	N/A	N/A	No. Kidding at home in March, April, May. Looking for contracts June - Sept. Breeding Oct-Nov at home.
Predator Defense?	Livestock Guardian Dog as needed - site dependent.	Yes, 1 large guardian dog, 2 border collies and 1 cranky Jack Russel Terrier, occasionally horses for large grassland sites	No	Yes. 2 Large Guardian Dogs, 1 herding dog,	N/A	6 guardian dogs- Maremma, Great Pyrenees, Kangal cross + donkeys	Eventually getting dogs but would be determined if necessary for specific sites	Livestock guardian dogs, currently has 4 (Kangal, Maremma)	1 Livestock Guardian Dog plus electric netting	Large Guardian Dogs and firearms	Large Guardian dogs and firearms	N/A	2 large guardian dogs	Livestock Guardian Dogs
H&S incidents/near-misses? Prevention?	Hail/Rain storm scattered herd and ruined Shepherd's phone. Prevention is 2X daily text check-ins and 24 hr local emergency contact for contracting agency. Owner circulates	Staff: awareness and education re handling personal dogs, large machinery (goats sleeping underneath, horsemanship skills, managing emotions in camp - conflict resolution, carry	Night pen near a public theatre that is shut at midnight. Intoxicated, unruly folks would try to mess with fencing and pet goats etc. Mandatory to park RV so can see the night pen and double fenced this	Goats cause falling rock/dislodge boulders on steep hillsides- plan herding positions and fencing accordingly, moving multiple panels at one time causes pinch points for fingers, people-	N/A	Carry water for herding dogs, biggest staff hazard during processing = fatigue =needle sticks Goats getting hung up in trees by feet or horns when grazing, goat fell in an open tar pit at	Goats tangled in control plot electric netting - used rebar stakes and wire fencing to prevent. Fighting goats can break legs and each others horns. People putting arms through fence and goats played	Goats get into a lot of trouble - has had some losses with entanglement with electric netting	Educating public NOT to feed goats (had several goats die because neighbors fed goats poisonous garden trimmings thinking they were feeding hungry goats - Rhododendron, Azaleas, Western	Public Education re: not feeding goats landscape/garden trimmings (Oleander is poisonous) and how to react to barking guardian dogs Helicopters scatter goats	Devils club poisoning- high risk for shepherds Sheep get stuck on their backs in ditches, humps/bumps, hollows then vulnerable to bird attacks Prone to choke and	N/A	Unhappy neighbors with wandering guardian dogs Goat escapes on public roads	Yearlings in a new site ingested ornamental plants to toxic levels and were quite ill. Prevent by feeding goats before entering a new site (full belly eliminates overeating a toxic

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	contract sites regularly for quality control and staff support.	water for herding dogs (dog darted to puddle on side of busy road for a drink), discuss hazards with staff in advance	area with construction fencing. Danger from charging off leash dogs. Herders phone # on site signage for emergencies- i.e. escapees. Can add contracting agency to insurance-see your insurance provider about this	drunk folks unhappy with goats on site or neighboring their property, predators-bears are opportunists		gravel site (human error forgot to cover it)- it managed to climb out but tar is still coming off in rubbery chunks (all holes are dangerous because they like to explore) Cougar or coyote attack (killed 10 goats previous night)	roughly with them - entrapment danger for hands/arms- required signage to remind people to look only. NEED TO MONITOR HERD AT ALL TIMES FOR GOAT AND HUMAN SAFETY		Yew) Bored teenagers messing with fences/setting off fireworks Goats WILL get out - need 24 hour supervision	All gear should be repaired and in good working order before site access Goats need to be trained to electric fence Hike all sites for predators, booby traps, and poisonous plants	bloat on rich feed. Wet wool creates environments for flies and maggots. Always have meds and vet tools on hand Sheep with full fleeces get completely trapped in blackberry			dose of a new plant, provide a variety of forages at all times, don't allow any people to feed goats (kills with kindness).
Herd vaccinated and what vaccines?	Yes. Full vet checks done, blood work for Johne's, Caseous lymphadenitis management.	Yes, 8 way vaccine and boosters for kids	Yes, CDT (*Clostridium perfringens type C + D and tetanus), herbal worming treatments, closed herd	Tasvax - 8 way	N/A	Glandvac 6 plus Caseous Lymphadenitis	TASVAC-8 *local show goat community doesn't like goats to be vaccinated for Caseous Lymphadenitis because then they always test positive for it	Tasvax	Yes. CDT (Clostridium perfringens type C + D and tetanus)	Yes, Blood Test for Caseous lymphadenitis, Johne's, CAE (Caprine arthritis encephalitis), and Q-fever	Yes	N/A	Yes, couldn't remember name	Tasvax
On-site Management Needs: (Staffing, security, accommodation, etc.)	24 hour staff presence, and good working relationship with By-law and Police	On site 24/7 Camper for staff, will need to add another as contracts get bigger/longer Flat night pen area with shade/shelter if possible,	Self contained with RV and stock trailer, Electric fencing, shade/rain shelter	Access for 24 hour supervision, create a home base where goats, dogs, and herders can relax when not working	N/A	N/A	Own accommodations near night pen	Travels as self contained unit Request for city enforcement of dogs on leash Night pens close to camper to prevent prankster trouble Carries a firearm	Self contained unit	Self contained truck and camper	N/A	N/A	Hoping to be self-contained unit.	Night time shelter is very important to protect from large predators (wolves, cougars etc.) in rural areas
Site Attributes / Conditions: What is required of the site, topography, water, access trails, etc.	The most shade/cover for night pens, moved as needed, "sacrifice zone" Permission to remove poisonous plants (lost 7 goats to native milkweed), handwork to establish trails for fencing by contracting agency or practitioner	Good road access for trucks/trailers, campers, shade/shelter	Only works on sites less than an acre, Difficulty of site, rocky, steep, site prep, need removal of biomass for electric netting fence line/access trails, parking for RV and appropriate bylaws so they can park RV on roadsides and in residential areas near goats		N/A	N/A	Partially fenced or ability to back up to a building to require less fencing infrastructure. Water access, road access for work vehicles, access/management for public viewing to encourage public support ***access to a mixture of different forages during contract for goat health	High chain link fenced area is amazing to access Mixed forage access in essential for goat health	**Size** of site/project (to meet his herd size) **Access** for vehicles/goats (does he have to set up camp elsewhere and walk goats to site) **Type** of Vegetation (are there poisonous plants, rate of impact required) **Timing** is key!	Must have a site visit to assess accessibility and to make a viable long-term plan for site goals	Pay attention to terrain dangers Long rectangular pastures work better as sheep eat while migrating	N/A	Water access and road access to campsite area	Safe fencing, sites not too rugged for people, easy access for transportation vehicles, safe locations for single woman working alone, time of year is key (not during kidding), some sites with large monocultures goats are the wrong tool (ie. straight burdock- better to bulldoze as not enough other forage available)
Unintended Consequences: (e.g. erosion, compaction, damage to non-target plants, biosecurity concerns, spread of weeds in feces, etc.)	Moving the herd through a sensitive area is better than fencing to prevent damage to non-target plants Weather affects the palatability of some plants VERY SITE SPECIFIC!!	Goats can ring bark of trees- wrap with hardware cloth for protection, move tether locations of horses frequently , Perception that sometimes the camp looks worse after longer stays because of the high impact but long-term impacts are negligible- this is often weather	Girdling of trees and eating bark-wrap trees with burlap and twine, ask which trees are expendable Requires clear communication about what needs to be protected in grazing area	Erosion of open banks (goats play on steep hills and rocks), unstable slopes suffer a "slow levelling" which is not necessarily bad=controlled erosion, ground disturbance (hooves/imprints) create greater water holding capacity	N/A	No problems to date on farm, rotational grazing limits parasite load	Awareness of native/rare plant species and actively protect them as well as poisonous plants (Rhododendron), goats have less impact than machinery/mowers, but can still move loose gravel on hillsides and dislodge larger rocks.	He moves night pens often to reduce high impact. Discuss in advance what species of plants/brush are to be avoided, and ways to lessen impact or agree upon impact levels (example of wolf willow being eaten about 30% while grazing spurge, long-term impact to	Spread of weeds (mature Broom seeds possibly remain viable after ingesting), potential for "trailing" or wearing paths Don't take any plant down to bare ground, need root system to avoid erosion, especially on steep hillsides	Focus on Animal Management. Example: Hawaii-Lava Bed-used "edging hedges" to deposit nutrients on the lava to establish grass. Can take decimated land and rehab it with management. Hard dry seed can be transferred/redistributed. She grows	Uncovering "unexpected things" i.e.. Homeless camps, poisonous plants, holes in structures used as fencing that then become escape routes for animals	N/A	Biosecurity in area with access to bighorn sheep (Movi (Mycoplasma ovipneumoniae) disease transfer)	"Tree destruction-goats eat lower limbs and bark of young pines and fir, be conscious to not overgraze, fence off riparian areas to eliminate any damage

Interview Questions	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11	Practitioner 12	Practitioner 13	Practitioner 14
		dependent also, rain creates mud in high traffic areas and heat burns the grazed areas and makes it look browner compared to the green lush growth that precedes the introduction of the goats					Island show goat breeders are concerned re: disease transmission of MOVI (Mycoplasma ovipneumoniae) (not likely because that is a mountain sheep issue) and Caseous Lymphadenitis	willow negligible but client didn't like the visual outcome)		the seeds in Feces in "poo pots" to see what is still viable in the feces. Seeds take 2-3 days for passage from rumen-can hold on site for 5 days with high quality forage before moving to another site if seed transfer is a concern. Have the ability to open up closed waterways (ponds) and increasing biodiversity by knowing the needs of all animals in the area and using the goats to re-create the appropriate habitat.				
Actively training to eat invasive plants or pasture grazing? Which plants?	Yes, sometimes takes up to a week to introduce goats to a new plant, introduce goats in the thickest area first, fence in if required to get them to eat it and develop a taste for it, then they will seek it out. 95% of their current work is Leafy Spurge, 5% White Top is new this year.	Actively training by herding on dense patches of target species, sulphur cinquefoil, leafy spurge	basically pasture grazing, with support of herder to target the appropriate biomass(pulling or cutting tall plants for goats to access) and protecting the appropriate plants by wrapping or fencing goats out of an area	Goats gravitate to the densest brush for big mouthfuls (good value for their time),hand feed new plants in night pen the night before grazing to develop a taste- phragmites, knotweed	N/A	Hold them on blueweed- very plant specific timing for the goats, right plant at the right time (i.e.. they will walk by a plant for 3 weeks until it is "just right" and then they eat nothing but that plant for a period of time)	Yes, introduce by hand feeding in night pen	Yes, keep putting them on new plant, penning if required and be patient	Yes. Russian Olive- took a few days to utilize new plant. Would be a good idea to introduce new plants in advance of contract if possible. Mob grazing increases potential for selection of new plants because of the variety available - competition and curiosity by goats	Lets goats manage their own toxicity levels by ideally providing a variety of forage (mixed vegetation is IDEAL) and observe what they are eating and when. Goats prefer poison ivy in January versus summer when it is most toxic. Apply multiple grazing sessions to target plants when goats want to eat them.	pasture grazing, but managing location by actively herding for intense grazing. There is high value in training animals to eat available forage even if it isn't their preferred forage.	Active training and herding is a priority versus pasture "free" grazing Takes about 3 days to teach a goat to eat a "new" plant species,	Not yet, pasture grazing for brush control	Positive Consequences- goat and sheep manure have increased her pasture production and native grasses are increasing as brush is pushed back"
Social Media: Do you utilize social media, does it help with public management, what type of social media do you use (Twitter, Instagram, Facebook)? Is there a cost to your business to run it?	Facebook, Instagram, webpage (mainly for public education and visitors - few contracts come from social media), Goat Yoga (when requested), regularly presents to grazing groups or anyone requesting presentations (i.e.. Oldman River Watershed Council), public speaking,	Facebook, Instagram, You Tube channel- these are difficult to maintain because of time constraints and internet/phone access in remote locations, will probably need to pay someone to help with this as it requires dedicated time	Facebook business page, Webpage, photo updates from sites while working, no cost, but doesn't love using social media	YouTube Bradley Working Goats and website centered ($300/year), they direct traffic to each other, business cards during networking meetings etc.	N/A	Facebook- free + occasional advertising on that site but most of their business comes from word of mouth for breeding stock	Mostly word of mouth at this point- neighbors and friends, website and Facebook page in progress	Yes. Infrequently updated Facebook, prefers if contracting agency handles public messaging	Yes. Partner at home posting pictures on Facebook helps followers know where the goats are. Also Home Owner Associations are big supporters and help to educate public RE: dogs on leash etc. No cost	Website, Facebook	Website, Facebook	N/A	No but will in the future. Currently providing good written data to share with potential clients	Knows the process but not needing to introduce new plants at this time
Public Management Needs: Any public management needs that haven't been covered? Traffic control, public visitor	Some cities want full control over public relations, Robert partners with whatever the city needs/wants. Can have up to 300	Not a petting zoo - no touch policy, Covid-19 so no public visiting goat camp this year.	Education: goats are working, not a petting zoo (keeps goats away from fenceline and focussed on weeds, non-transmissible	Hand sanitizer on site for public touching goats (ORF [Sore Mouth Infection] transmission)	N/A	N/A	It is key that the public be educated that grazing is a tool/process that is effective and that they have a positive experience too	Escape routes (at least 2) and safety plans	Not a petting zoo- goats need to be eating weeds not waiting at the fence to be hand fed Signage and newsletters/comm	Utilize local Community Watch Program, develop a good rapport/partnership with police and fire services as these	Ideal to drive truck and trailer to site and unload into the fenced area to avoid having to herd to a site in an unfamiliar area	N/A	No	Facebook, Instagram, Website

Interview Questions	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11	Practitioner 12	Practitioner 13	Practitioner 14
access, dogs on leash etc.?	people per day stopping by to see goats Requires a "no touch" policy- dogs, goats and shepherds are working, pictures only, works closely with By-laws and Police to establish good relationship re: Dogs on leash and night vandals, police to night drive-bys for prevention By-law invited to issue off leash tickets		disease to humans or dogs, clear and reasonable expectations for all parties, view the final product (they don't eat EVERYTHING)), the poop left behind is "a little something to remember us by" and is good for the soil - no need to pick it up						unication are important Evenings are very busy with visitors to goats- it is appreciated for herders to get a break from the public	are good opportunities to develop youth education programs	with uncontrollable unknowns.			
Other Considerations? Any other considerations for effectively implementing targeted grazing?	Attitude and desire for positive outcomes determine a successful enterprise by both parties, collaboration to problem solve. TIMING is everything, acceptance of a learning curve as every site is unique.	Educate public: you don't have to touch the goats to interact, observation is a part of learning what the goats are doing. Set up for success by communicating before, during, and after. Get in touch with community associations and build relationships , creates great volunteer support, great local knowledge and suggestions for problem solving Would prefer to graze earlier in the season and more often to mimic the natural grazing of wild animal as the plants are more palatable earlier in their growth cycle (plant dependent)	Concerns from Union employees regarding goats taking jobs from people. Education and realistic expectations! Emphasize: quiet and relaxation that goats stimulate in park areas (no noisy machinery), they don't disturb the natural ecosystem (birds nests, baby rabbits and deer are unscathed by working with nature), we try to exceed expectations but don't overpromise and under deliver. Concerns re: tagging and traceability, cost prohibitive for producers and who admins?? Appropriate by-law amendments/ restrictions for who, how long, herd size, where, RV Parking, herding dogs off- leash allowed	Municipal employee to act as liaison to handle public access/education etc. Pay attention to parasite control in Lower Mainland Biosecurity should include not mixing different herds on one site Establish a "season" in an area with multiple adjacent sites to make it cost effective for both parties, put a grazier on a yearly "retainer" paid monthly for a certain number of grazing days per season as this allows more flexibility for hiring agency to target optimum grazing times of plants and develops grazing capacity of grazier (to retain trained stock and maintain herd numbers- takes 2 years of repetition and routine to develop a quality herd - especially for urban environments), a home farm base to rest between sites and to hold sick or injured stock	Challenges: public opportunistic theft of goats at certain times of year, opening of fences "freeing" stock, secure fencing requirements - animals need to be trained to electric and will still run through it if frightened	It takes the animals time to adjust to new sights and sounds (took about a week for her goats to adjust to large machinery in the gravel pit and not startle and stampede). **Reliable** staffing for city contracts, education for public and support network for herders (i.e.. the ability to remove sick or injured stock immediately from a site) to maintain positive PR, concerned about PETA and harassment/criticism of animal management. Moving and Managing a herd is very COSTLY so it has to be monetarily worth it for a herder to put themselves under the scrutiny of the public and expose their animals to the hazards of the city	Proactive BYLAW AMENDMENTS: allowing goats in metro areas, one license/inter-community license to allow practitioners to work in multiple municipalities (including private sector land not just for the municipality) and thus reduce prohibitive costs and repetitive "hoop Jumping "for each district Encouraging public support with "citizen science"- family involvement, education days, school visits, establishing long-term stewardship plans- native planting after invasive removal, school monitoring projects/partnerships would also like to see more cooperation among practitioners, discuss mitigating procedures for disease transmission prevention in advance of contracts	Develop a plan and work together as contractor and contractee Consider reputation, ethics of grazier, need to consider more than just the lowest bid Every contractor should see or have access to a site before bidding process- every site has very specific challenges Kiko goats may be able to handle rainy conditions better than others	It is a challenge to get commitment to 3-4 years of plant management at a site-multi year approach with secure funding. There is a difference between "maintenance" of a site and "serious change of an ecosystem"-Experience/References. This expected practitioners to have a long-term management plan by asking the question "how would you approach this site with the tool of goats?" Contracts should not be awarded by price alone- "you get what you pay for". The business challenge is to know where you are working and what other tools you are competing against...this determines the value/cost of the tool	Discuss and make a landscape plan, allow the Practitioner to do the work to meet the goals of land and forage needs of goats, utilize before/during/after photos and insights from previous projects. Sometimes agencies don't understand the costs of accomplishing what they think they want. It is often a PROCESS and takes time. Utilize the goat tool appropriately and effectively i.e. "pugging"- taking down vegetation with goats and planting trees afterwards (forestry in California)	Trampling vegetation with mob grazing has a beneficial effect as well as consuming the weeds Dry ewes or wethers would be most effective- nutritional requirements are not as important from a producers viewpoint Hire local animals because they will already have a palate for local plants	N/A	Seeking larger tract contracts for brush control and fire mitigation to coordinate with other services offered by partnering enterprises, and to limit transportation expense and stress on animals. Imagine window washing large buildings (start at the top and work to bottom...then start all over again...and repeat.)	Education for positive pubic interactions with the process, developing an understanding of using livestock to manage landscapes by informing about the type of livestock, when and how the are used.

Interview Questions	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11	Practitioner 12	Practitioner 13	Practitioner 14
Do you know any other practitioners willing to be interviewed? Best way to contact them?	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	Yes, Tammy contacted	No	Make sure animals have access to a variety of forages to manage any toxicity problems. Was considering running a wether herd to reduce the toxicity dangers to reproduction and extend the grazing season. Provide a science connection available to the community through children's school programs and possibly university programs.
Target Plants Grazing Frequency: How often does site need to be grazed during growing season? How many years/seasons on each site?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**Ivy-**1 treatment each year for 2 years, cut vertical vine stems on trees **Blackberry-**effort required, 2x per year is minimum, early in season to get new cane growth while young, suggested following up with Pigs **Scotch Broom-** goats will eat all tender bits and will remove the bark from larger stems too, can reach 4-5 ft height, will eat seed pods, concerned over transport of mature seeds in feces, plant has huge seed source and huge seed bank in soil, requires high intensity grazing but must be aware of what else you are impacting **Knotweeds-**a friend has grazed cows continuously on it in riparian area with success	**IVY-**goats need a daily feed on quality forage then access ivy to offset toxicity **BLACKBERRY**- graze at leaf out while stems are soft, can fence in but still need access to other forage too, repeat following spring, use short-haired dog **SCOTCH BROOM**- high in estrogen leads to abortions in does. Use wethers, sets back maturity of your animals so pull off 3 weeks before flowering	N/A	Blackberry- remove old canes, put goats on regrowth	N/A	No. Knows a few people who are interested in starting in small animal farming. Land access is always an issue for young farmers.
Target Plants Timing of Grazing: What stage of lifecycle is best to graze plants? Timing during growing season (early spring, June, July, etc.)	N/A	N/A	See above	N/A	N/A	N/A	N/A	N/A	See above	N/A	Sheep will eat all flowers first of any plant Sheep prefer everything in the spring - new growth	N/A	N/A	N/A

Interview Questions	Practitioner 1	Practitioner 2	Practitioner 3	Practitioner 4	Practitioner 5	Practitioner 6	Practitioner 7	Practitioner 8	Practitioner 9	Practitioner 10	Practitioner 11	Practitioner 12	Practitioner 13	Practitioner 14
Target Plants Efficacy of Treatment: Information on how effective treatments have been in past for reducing invasive plants and/or controlling spread. Willing to share any formal reports regarding grazing program? How to access them?	N/A	N/A	No formal reports, 6 years of observation. Most people hire based on budget and do not graze often enough to be effective or do the next steps after the goats remove the majority of the biomass (ie. dig root mass, clip new growth, mow etc.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

APPENDIX 3: OPERATIONAL GRAZING PLAN AND MONITORING PROTOCOL

Operational Grazing Plan

Outlined below is a grazing plan that incorporates treatment of high priority and low priority areas, as deemed by Metro Vancouver Regional Parks staff. The Grazing Plan outlines treatment for 3 years but is organized such that the 'Plan' can be on-going with the addition of 2 new high priority polygons each year and the restoration of 2 polygons each year. Site-specific assessment information is noted in the Aldergrove Regional Park Site Assessment below.

Aldergrove Regional Park Site Assessment:

Consideration	Information
Existing Shelter(s)	• Existing barns could be used in this park • The Red Barn is a great structure for holding livestock during rainy season, cleaning would be a consideration ○ Fee for service agreement would be helpful
Potential Basecamp Areas	The Red Barn is excellent basecamp, would allow for effective treatment of target areas throughout park
Water Sources	Regional Parks could haul in water for practitioner, there are water resources (taps, troughs) on site
Penning Locations	Barn, current horse pen area north of red barn could be goat tight with potential repairs
Loading/Unloading	The Red Barn, basecamp area, excellent access
Access/Egress Routes	Good access into basecamp area. Road access throughout southern section of park
Existing Fences and Type	Fencing is inconsistent, 4 strand barbed wire and some page wire. Interior pasture fences seem to be under large blackberry thickets. Perimeter fencing is not necessary to contain goat herds under adequate management
Hazards - Inside Park	Dogs, coyotes, fencing
Hazards - Outside Park	Zero Avenue, relatively busy road
Toxic Plants	No toxic plants noted - nightshade seen on west side of park outside of treatment area. Practitioner should do walk-through to ensure no toxic plants present prior to initiating grazing treatments
Power Sources	The Red Barn has power
Public Viewing Areas	• Public use is concentrated on north side of park, have usually 600k visitors per year, but closer to 1 million this year. • Visitors usually stay away from south side because they think it is private and there isn't easy access to that side of the park • Potential to put up signage to deter use • Public viewing areas not a priority or desire

Consideration	Information
Plants/Vegetation to Protect	• Moist draws ○ Western toads use draws, maybe Oregon forest snail (1 sighting in park) red legged frogs, painted turtle in ponds • Mature trees and younger restoration trees
Riparian Zones	Will not be included in treatment area
Predators	Coyotes along escarpment – would necessitate use of livestock guardian dogs

Based on the scope of Himalayan blackberry monoculture polygons and the limited budget for invasive weed management the following grazing plan provides a cost effective and efficient long-term solution for Aldergrove Regional Park. Aldergrove Regional Park has a unique infrastructure assets available to support targeted grazing, primarily the Red Barn and associated corrals, which could be used to house a full-time target grazing goat herd on site for a minimum of 3-5 consecutive years, concentrating grazing pressure on identified priority blackberry areas, with additional capacity to opportunistically address other invasive species noted across the southern portion of the park (Canada thistle, wild chervil, stinging nettle, hairy cat's ear, narrow-leaved plantain, St. John's wort, common tansy, lamb's quarters, shepherd's purse, mustard, chicory, cleavers).

A potential full-time herd would consist of 50 goats, 1 herding dog, 1 or 2 large guardian dogs (to provide livestock protection from off leash dogs and coyotes) and 24-hour supervision by a shepherd. Due to the aesthetics of the park, active herding is recommended for the majority of the sites over passive fenced grazing. With active herding, the shepherd is present continuously, uses the herding dog(s) to mobilize the goats and uses fences sparingly. With passive fenced grazing, the shepherd corrals the goats using fencing and contains them in one location. High intensity grazing can be achieved through either fencing or herding, fencing infrastructure is not necessary if active herding is utilized.

Metro Vancouver Regional Parks personnel would determine and assign the high priority polygons for eradication of Himalayan blackberry. As available, the goats would graze lower priority polygons throughout the year with a specified plan that applies consistent control and will establish natural competition, regeneration, and biodiversity. This plan reclaims 1-2 polygons per year consistently to facilitate long-term management of Himalayan blackberry by Regional Parks staff and provides grazing pressure to mitigate spread of blackberry and reduce biomass from non-priority polygons.

Of the five 'willing-to-travel' targeted grazing practitioners estimates for economic incentive from ranged from a minimum of 6 days per visit to 28 days per visit. Treatments must be applied twice annually during the growing season, resulting in estimated cost projections of $12,000-$56,000 per year for targeted grazing treatments. If a resident herd is implemented, then the grazing plan outlined below is recommended. According to Tammy Salmon (co-author), 40 grazing days per year would be adequate. If intermittent grazing occurs, then two visits per year would be required (Spring and Summer) and the length of each visit would be highly dependent on the size of the treatment areas. The minimum number of days required to secure a targeted grazing herd is 6 days.

YEAR *1*

Early Spring

- Graze **High Priority Polygons A and B -** 7-14 days of high pressure, fencing in of grazing goats daily, cutting and pulling canes over for goats to access top growth, reseed bare ground, re-graze every 4-6 weeks for 1-2 days though summer to manage regrowth and stress root systems

All Season

- Graze **Low Priority Polygons C and D** as availability allows to fulfill # of contract days

Year 2

Early Spring

- Shift **Low Priority Polygon C and D into High Priority** – 7-14 days of high pressure grazing – follow high pressure grazing protocols outlined above

All Season

- Re-graze **High Priority Polygons A and B** once in Spring and Summer to control regrowth
- Graze **Low Priority Polygons E and F** as herd is available to fulfill contract days

Year 3

Early Spring

- Shift **Low Priority Polygon E and F into High Priority -** 7-14 days of high pressure grazing – follow high pressure grazing protocol outlined above

All Season

- Re-graze **Polygons A, B, C, and D** once in Spring and Summer to control regrowth.
- Stop adding Low Priority Polygons

Fall

- <u>Consider</u> restoration planting of **Polygons A and B** if blackberry has been depleted. Protect native species planted by temporarily wrapping with burlap or fencing goats out of newly planted areas with temporary solar electric netting

Year 4

Early Spring

- <u>Consider</u> collecting post-treatment grazing data using the Field Monitoring Datasheet (Figure 3)

All Season

- Re-graze **Polygons A, B, C, and D, E and F** once in Spring and Summer to control regrowth.

Fall

- <u>Consider</u> restoration planting of **Polygons A and B** (or Polygons C and D if Year 3 restoration planting occurred) if blackberry has been depleted. Protect native species planted following procedures outlined above

Year 5 – depending on results from Year 4 assessments

All Season

- Re-graze **Polygons A, B, C, and D, E and F** once in Spring and Summer to control regrowth.

Fall

- <u>Consider</u> restoration planting if blackberry has been depleted. Protect planted native species following procedures outlined above
- Collect treatment data using the Field Monitoring Datasheet (Figure 3)
- If appropriate, collect restoration planting parameters such as survival, growth, and grazing damage.

Monitoring for Efficacy

To understand the impact of targeted grazing on invasive species, and ecosystems in general, a field-testing and monitoring program must be implemented *prior* to the initiation of the grazing plan. The field-testing recommendations and monitoring protocol outlined below are specific to Aldergrove Regional Park but can easily be transferred to other parks with Himalayan blackberry. Himalayan blackberry is somewhat unique in its growth habit and size of infestation, which presents monitoring challenges. Himalayan blackberry uses scaffolding, such as fences, trees, and even itself, to reach heights of 5+ meters. Because of heights reached, standard (1 m^3) exclosures are not feasible. Instead, 2 reference polygons will be used to compare treatment efficacy. The reference polygons will not be grazed during the study. A field-testing and monitoring program has been designed that is intended to be quick and versatile for Metro Vancouver Regional Parks staff to implement.

Field-Testing Recommendations

There are a number of suitable polygons that can be used for the field-testing portion of the program. As outlined in the Grazing Plan, the Metro Vancouver Regional Parks staff will select 2 high priority polygons for treatment in Year 1. We recommend selecting a nearby, ecologically similar, polygon to serve as the Untreated Control. The Untreated Control polygon will not receive any grazing during the duration of the study, goats could be fenced out of the polygon using metal T posts and page wire; or through active grazing procedures.

Measurements to take at polygons A-F and two untreated Control polygons in the fall prior to initiating the study include:

- Area of each polygon – carefully walk the perimeter with GPS unit
- Maximum height of each polygon – use a clinometer or Range Finder
  - Height and area will be used to determine maximum volume
- Average number of floricanes (2nd year woody canes) and primocanes (non-woody shoots) per m^2 – cut back growth at 5 locations around perimeter of polygon to expose woody canes and primocanes.
  - Use a 1m^2 quadrat to count number of woody canes and primocanes per m^2
    - Within Five 1m^2 quadrats per polygon assess average percent bare ground and cover of any other plant species.

Monitoring Protocol

Monitoring is necessary to assess the efficacy and success of targeted grazing treatments, and provides feedback on the rate and direction of site characteristic changes (Bailey et al., 2019). Monitoring of treatment effects must occur at the same time each year. It recommended that monitoring occur in late June through to early August as to capture maximum growth of Himalayan blackberry and other plant forms.

In Year 3 (Late June) of the program treatment measurements taken within Polygons A and B and two untreated Control polygons include:

- Area of each polygon – carefully walk the perimeter with GPS unit
- Maximum height of each polygon – use a clinometer or Range Finder. The height and area will be used to determine volume
- Average number of floricanes canes and primocanes per m^2 – at the Untreated Control polygon it will be necessary to again cut back growth at 5 locations around perimeter to expose floricanes and primocanes. Use a $1m^2$ quadrat to count number of floricanes and primocanes per m^2. At High Priority Polygons A and B, it will be possible to walk into the polygon and make measurements
- Number per m^2 of:
    - Shrubs
    - Trees
- Percent Cover per m^2 of:
    - Other, invasive species
    - Agronomic grasses
    - Native grasses
    - Native forbs/ferns/mosses
    - Bare Ground

Below is an example of a Field Monitoring Datasheet for Himalayan blackberry.

Location: Aldergrove Regional Park – Blackberry Targeted Grazing Project	
Sampling Date:	Sampled by:

High Priority A	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	AVERAGE
# Floricanes						
# Primocanes						
# shrubs						
# trees						
% cover other invasives						
% cover agro. Grasses						
% cover native grasses						
% cover native forbs/ferns/mosses						
High Priority B	**Quadrat 1**	**Quadrat 2**	**Quadrat 3**	**Quadrat 4**	**Quadrat 5**	**AVERAGE**
# Floricanes						
# primocanes						
# shrubs						
# trees						
% cover other invasives						
% cover agro. Grasses						
% cover native grasses						
% cover native forbs/ferns/mosses						
Untreated Control	**Quadrat 1**	**Quadrat 2**	**Quadrat 3**	**Quadrat 4**	**Quadrat 5**	**AVERAGE**
# Floricanes						
# primocanes						
# shrubs						
# trees						
% cover other invasives						
% cover agro. Grasses						
% cover native grasses						
% cover native forbs/ferns/mosses						

Figure 3. Example of field sampling data collection form.

To effectively address Himalayan blackberry infestations in Aldergrove Regional Park the operation grazing plan, field testing recommendations, and monitoring protocol should be implemented. However, grazing pressure must follow the grazing plan to fully address the infestation If grazing pressure is not sustained efficacy will be reduced. Active herding management should be utilized for targeted grazing in Aldergrove Regional Park to reduce the need for fencing infrastructure and provide aesthetic values more in line with park objectives.

The logistical considerations outlined in Table 15 should be thoroughly reviewed to ensure that municipal partners are able to adequately support implementation of grazing treatments at Aldergrove Regional Park, with thought given to the opportunity to house a herd on-site and enter into a working partnership with long-term goals through implementation of a fee for service agreement allowing use of infrastructure.